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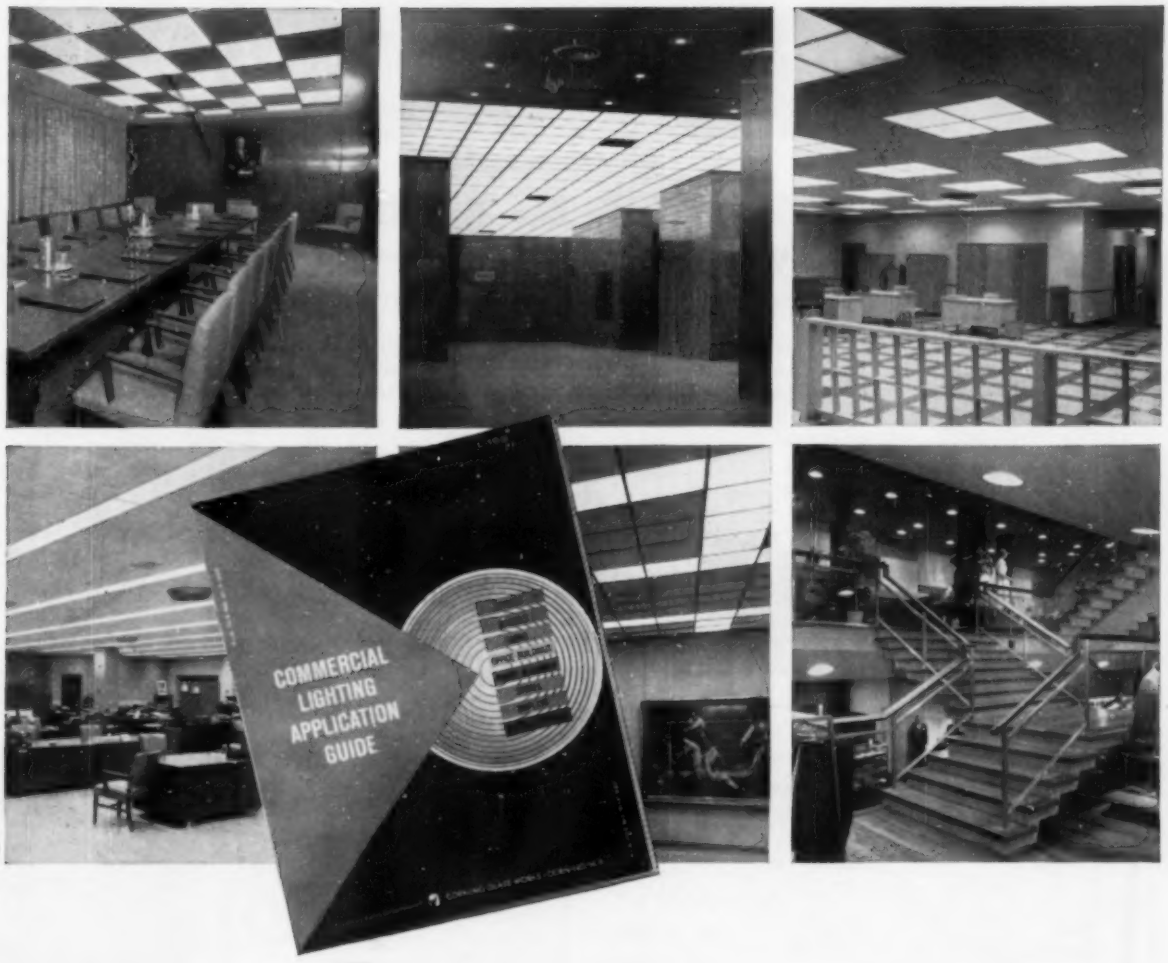

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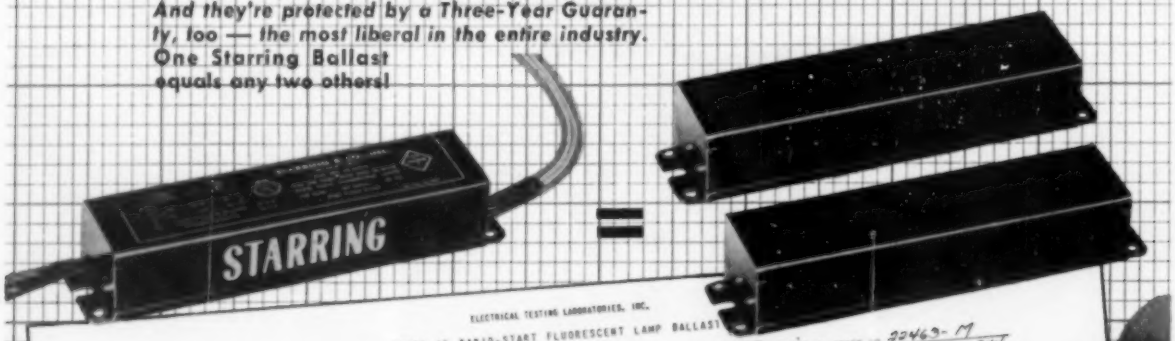

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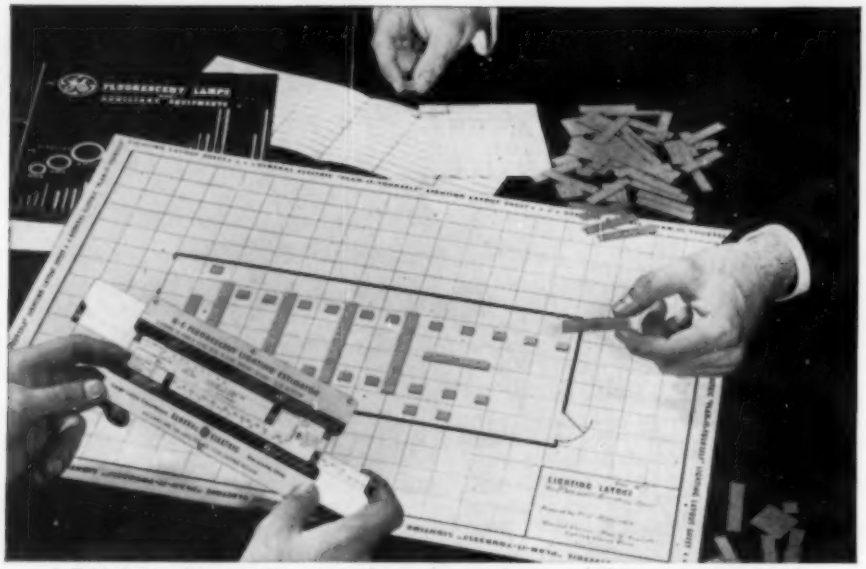

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Young eyes need good lighting, the taxpayers deserve a "break" — these were the considerations governing the choice of exposed precast concrete construction and LITECONTROL fixtures at Southwest Consolidated High School, Forsyth County, North Carolina.

Not only are the concrete beams exposed in this very unusual new school but it also has a precast roof deck. Result: a very low cost of $7.23 per square foot *complete*, for 21 classrooms, all-electric kitchen, cafeteria and gymnasium.

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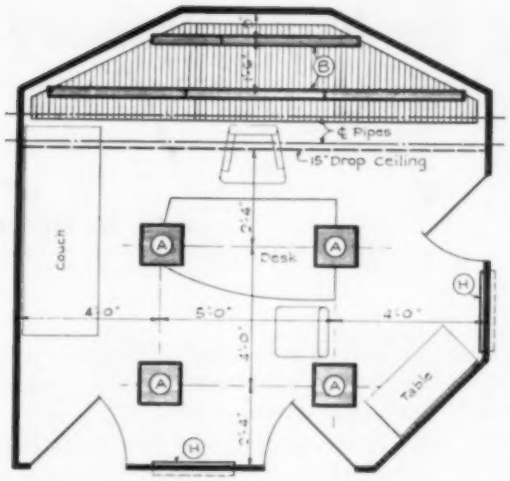

A Doctor's Basement Office—

remodeled with light

FROM ITS present appearance, one can scarcely believe that this attractive, modern, doctor's office was once a stark basement area. Lighting was from bare circline lamps. Heating was from an overhead radiator mounted horizontally about six inches below the ceiling. This in its turn was connected to hot water supply pipes which ran through the room on their way to radiators on the upper floors of the building.

The room, in the basement of the doctor's home, is 13 feet by 13 feet with a 7-foot 8-inch ceiling. Four recessed, louvered coffers using the 150-watt silvered bowl lamp (luminaire A in the drawing) are on 4-foot by 5-foot centers.

Unsightly overhead radiators were removed, but the pipes had to stay. Since they ran across the room approximately 4 feet from a wall, the ceiling in that area was dropped one foot three inches. This concealed the pipes and at the same time provided a cavity for a luminous ceiling 3 feet wide by 12 feet 9 inches long. Lamps used were T12, 430 ma, deluxe warm white rapid start, in two continuous rows on one-foot 6-inch centers (four 40-watt and one 20-watt) supplied by high power factor ballasts (luminaire B in the drawing). Shielding is vinyl plastic.

On the wall adjacent to the luminous ceiling a light background scenic wallpaper produces a realistic appearance of a huge window. In fact, the entire decor is well coordinated with the lighting system to make good use of light flux. Ceiling is white acoustical tile (80 per cent reflectance), walls are covered with light gray Marlite panels (40 RF), scenic wallpaper is 80 per cent, furniture, gray limed oak (20 RF) and carpeting is light gray (20 per cent reflectance).

Heating now is supplied by two 700-watt recessed electric baseboard heating units located as shown on the plan. These convectors have self-contained thermostats.

With a maintained level of 35 ft-c after seven months, the lighting design has successfully provided (1) an adequate level of illumination, (2) quality, both as to color and comfort; (3) a means of concealing ugly pipes, and (4) a heating system which is clean, convenient, easily controlled and economical.

Installation is by William P. Ackendorf, Niagara Mohawk Power Corp., Buffalo, N. Y. Western New York Section contest for My Most Interesting Lighting Job, second prize.

Some Factors Influencing the Night Visibility Of Roadway Obstacles

By D. M. FINCH

Interest in the night-visibility of the roadway scene is wide spread and has been the subject of numerous research efforts[1] of which this paper is only a small segment. We at the University of California have been working in various phases of this field continuously on an organized basis since 1919. This report covers one phase having to do with street lighting and its evaluation in terms of the visibility of objects under specified conditions of observation. The work included in this paper has been partially sponsored by the Illuminating Engineering Research Institute in a grant made to the University of California in 1952. This paper is a summary of the accomplishments made during the period of the grant (August 1952 to August 1955) and of the concurrent work done by graduate students with University support.

There are many factors that influence the night-visibility of roadway obstacles. We will probably never run out of combinations of variables to investigate. With such a situation confronting us it was decided to use the time tested procedure of isolating the parameters, holding as many as possible constant and then determining the effect of variations of a single quantity. One quantity that seems to be a key to the entire problem is the roadway brightness as seen by a vehicle operator. The effect of roadway brightness patterns on the visibility of typical roadway obstacles is the principal subject to be reported upon in this investigation.

As usual in research, several side-lights have developed as a result of the main activity. We have had to develop special instrumentation for both brightness measurements and visibility measurements. Also, we have had to re-open the question of size, shape and characteristics of obstacles, *i.e.*, whether to use a pedestrian, a box, a dog or cat, or an automobile as a typical target. Some data on various targets and a recommendation for standardization of targets is included. It would be very helpful in future work to have standardized targets used by most investigators.

The scope of this project is as mentioned above and the work has resulted in improvements to a previously reported "Instrument for the Evaluation of Night Visibility on Highways"[2] and data on the visibility of objects viewed against two roadway brightness patterns; (a) a very uniform roadway brightness, and (b) a very non-uniform roadway brightness. The balance of the paper will be a discussion of the technique of night-visibility measurements, a review of our outdoor street lighting laboratory and the results of some visibility measurements.

A Technique for Night-Visibility Measurements

Visibility is a rather indeterminant and intangible thing with subjective attributes that have to be perceived and interpreted by a brain before they become real. Thus if something is in a certain location but is invisible, it is below the threshold of perception; but if it is visible, it is above the threshold of perception. The perception threshold is the only satisfactory measuring point on the visibility scale because only at this point can an observer indicate with certainty (on a statistical basis) whether or not an object is visible. The problem is to reduce a supra-threshold visual scene to a perception threshold scene and then use the magnitude of the reduction system as an index of the supra-threshold visibility.

There are four parameters that can be used to reduce a visual scene to threshold, *viz*, size, time, brightness and contrast. All have been used effectively in visual threshold measurements for special purposes by various research investigators.[3] We have selected contrast as the control variable to use in our method since it seems to more nearly simulate roadway situations wherein the objects are generally large (greater than one minute of arc), time is substantial (greater than 0.01 second), and the average brightnesses are low and therefore

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 17-21, 1956, Boston, Mass. AUTHOR: Research Engineer, Institute of Transportation and Traffic Engineering and Professor of Electrical Engineering, University of California, Berkeley, Calif. Research sponsored as Project No. 37 of the Illuminating Engineering Research Institute.

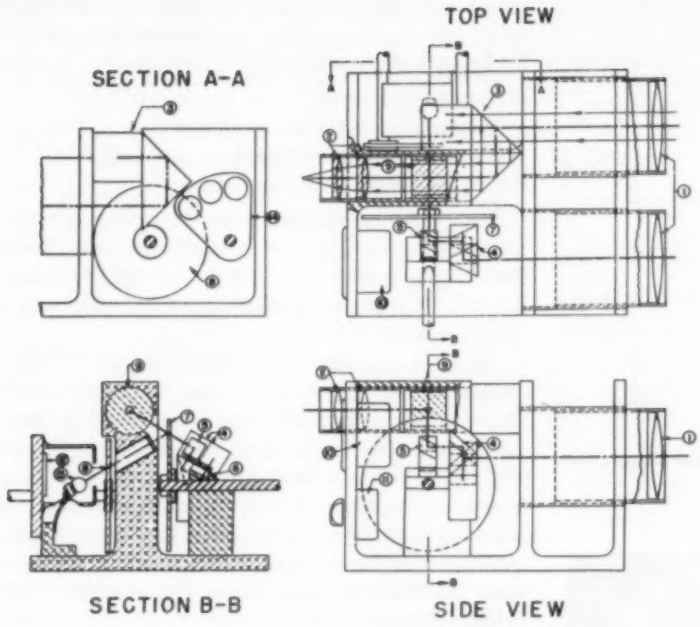

Figure 1. Details of visibility meter.

1. **Objective Lens—coated achromat 180 mm focal length.**
2. **Eyepiece Lens—coated achromat 122 mm focal length.**
3. **Binocular Prism 7 x 50.**
4. **Right Angle Prism.**
5. **Right Angle Prism.**
6. **Right Angle Prism.**
7. **Variable Transmittance Mirror (partial aluminum coating) — visibility index control.**
8. **Variable Density Wedge — background brightness control.**
9. **Object Mirror.**
10. **Ammeter — 100 milliamps.**
11. **Background Brightness Potentiometer.**
12. **Photocell-Round 1-inch dia., A-5.**
13. **Veiling Glare Source — 2.2-volt bulb.**
14. **Color Selector.**

should not be changed because one should maintain a constant adaptation level. Perception of most critical objects on the roadway at night is first by means of contrast and later the objects are resolved by means of critical detail (acuity).

The ground rules that we have established for our contrast-threshold instrument are as follows:[2]

1. The eye adaptation should be constant at the average value for the central field of the roadway.
2. Only a small central portion of the total field should be varied to determine the contrast- threshold (Visibility Index).
3. A change in the contrast in the central area should not change the average brightness of the field of view.
4. The total field of view should be large enough to include all glare sources normally within a driver's field of view.
5. A means for measuring the average brightness of the field should be included in the device.

The instrument that has evolved from designs and field tests covering the past several years is shown in Figs. 1 and 2. This design is our latest attempt to provide an optical path having a central field area of approximately two degrees wherein the contrast can be varied by decreasing the field brightness and simultaneously adding an equal amount of veiling brightness. A discussion of this principle and the equations for compliance have been given in a prior report.[2] The major problem in fulfilling the design requirements has been in the development of a variable density neutral filter and optical system that will allow exactly as much light flux to be added in the form of veiling glare as

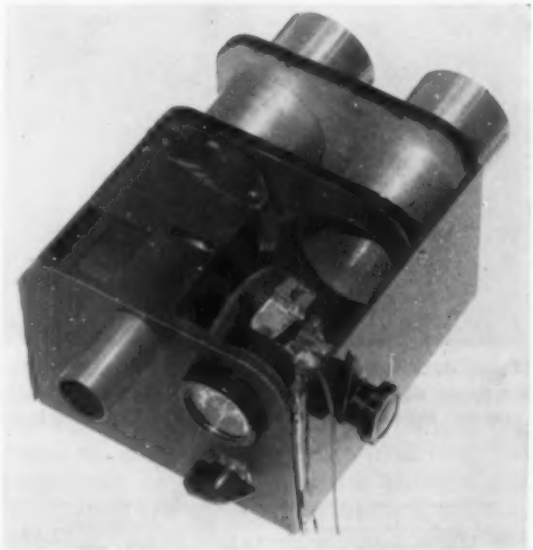

Figure 2. Photograph of visibility meter.

is subtracted from the central path. This is a necessary condition to maintain the average brightness at a constant level while changing the contrast.

The design shown in Figs. 1 and 2 incorporates a circular wedge made by depositing aluminum on a plane glass surface with a special evaporation technique so that the transmission varies approximately linearly with angular position. For a partial coating of metal on glass made by evaporating the

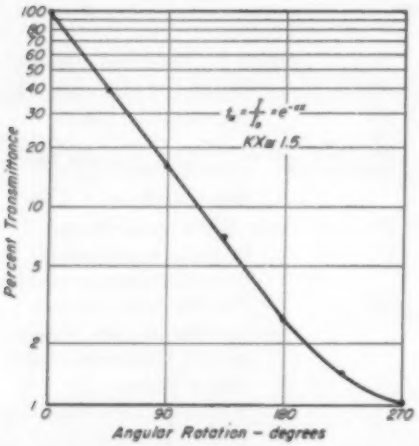

Figure 3. Per cent transmittance vs angular rotation of mirror using direct drive.

Figure 4. Variable transmittance partial mirror. Mirror in upper right. Drive cams and progressively closing fan type shield on left. Drive plate and holder in lower right.

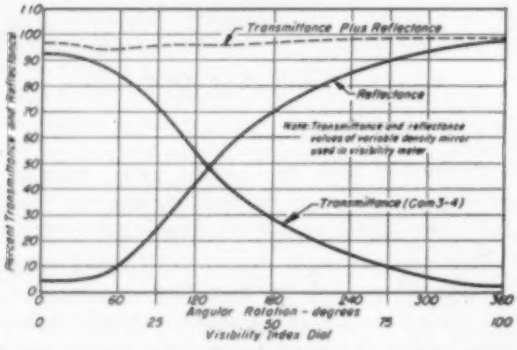

Figure 5. Per cent transmittance and reflectance vs angular rotation and visibility index dial — for glass mirror.

metal onto the glass under vacuum, the transmission was found to vary approximately exponentially with thickness, $t = e^{-kx}$, where:

t = transmittance
e = base for natural logarithms
k = absorptance (constant of material)
x = thickness

This phenomenon has been known to apply to many non-scattering transmitting materials (Beer's Law) but it was not evident in the literature whether it could be applied to metal films of only a few atoms in thickness.

To check the effect of metal thickness on transmission a disc was set up in our evaporation coating chamber and arranged to rotate under a semicircular shield at a uniform rate while the rate of deposition of metal was applied at a constant rate. A plot of the transmittance *vs* angular position on semi-log paper gives a straight line over 180 degrees of rotation as shown in Fig. 3 which indicates that the transmittance varies exponentially with metal thickness.

In order to obtain a circular filter in which the transmittance varies linearly with angular position it is necessary to deposit the metal coating at a non-uniform rate. The foregoing work indicated that the drive for the disc should be logarithmic since $\log t = -kx \log e$ which is a straight line function. A cam drive was subsequently arranged to operate a fan type of shield as shown in Fig. 4. This development permits the useful angular range of the filter to be extended to include approximately 320 degrees as shown in Fig. 5. The actual curve is not linear but it is much better than an exponential curve because small changes in angular rotation give about the same change in transmittance over the useful length of the scale.

The design requirements indicate that the total flux in the controlled contrast optical path should remain constant. This is now achieved by utilizing the transmitted flux for the object and its background and the reflected flux from the same area on the filter for the veiling brightness flux. See Section B-B, Fig. 1. The partial mirror has the desired property that the transmitted plus reflected flux equals a constant. See Fig. 5.

The instrument as now constructed is shown schematically in Fig. 1 and photographically in Fig. 2. The total field of view is approximately 15 degrees and the central field of view is two degrees. These limitations are imposed by the physical dimensions of the available optical parts and will be changed in future models to give a total field of view of approximately 30 degrees with a central field of two degrees. The field of view should be

large enough to include all of the principal brightnesses (glare sources and peripheral brightness patterns). The existing meter with which the data of this report were obtained does not have a large enough field to include the glare effect of the lighting units. Thus the visibility indices refer to the conditions without glare.

The instrument is calibrated both as an average brightness meter and as a visibility meter.

Brightness Calibration

To determine the average brightness the Visibility Index dial is set at 100 (minimum transmittance) and the Veiling Brightness source is adjusted for color (current and color filter) and brightness (variable density wedge in veiling brightness optical path) until the central field of view is visually balanced in brightness with the total field of view. It is only necessary to make this setting for the approximate average brightness so that the adaptation level is known and is not changed while varying the contrast. Our instrument has been calibrated by balancing the central field against known brightness sources over the range of 0.01 to 5.0 ft-L. See Fig. 6.

Visibility Measurements

The instrument will permit any object in the central field of view to be reduced to its contrast threshold. This is done by adding veiling brightness to both object and its background at the same time that the actual brightnesses of the object and its background are reduced.

The above is accomplished by rotating the variable transmittance partial mirror until by visual observation the object is at its contrast threshold. The dial has been calibrated so that the setting of the partial mirror is a measure of the supra-threshold contrast since it indicates the amount of veiling brightness necessary to reduce the actual contrast

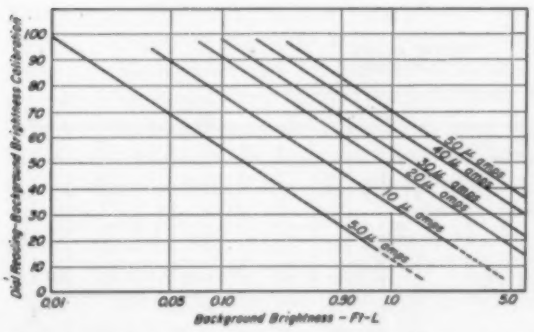

Figure 6. Background brightness dial calibration for visibility meter.

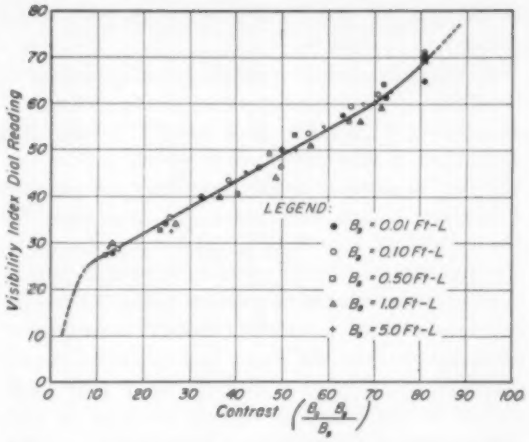

Figure 7. Visibility Index dial calibration for visibility meter.

to threshold conditions. The setting of the partial mirror for threshold contrast is used to obtain the "Visibility Index." Refer to the following section on calibration.

The Visibility Index is a measure of the supra-threshold contrast of the object as seen against its own immediate background. The concept of the "visibility index" can also be explained in terms of the calibration procedure.

Calibration as Contrast-Threshold Meter

A series of matte gray discs 3¼ inches in diameter having reflectances from 11 to 80 per cent were mounted in the center of a matte white field with a reflectance of 80 per cent located approximately 10 feet ahead of the instrument. The visibility meter was sighted at the test field so that the gray disc was in the center of the central field of view. The illumination on the test field was varied to give background brightnesses from 0.015 to 5.0 ft-L. The brightness of each gray disc was measured and checked by calculation. Thus the actual contrast in the field of view was accurately known.

The visibility index dial was then rotated to the position of minimum transmission and the brightness of the veiling glare source was adjusted to the same average brightness as the surrounding. The visibility index dial was then rotated until the contrast of the gray disc on its background was visually observed to be at the contrast threshold. The dial reading was recorded and many repeat runs were made for each contrast and background brightness level. The results are shown plotted in Fig. 7 and indicate that there is no observable effect of background brightness. This is advantageous because then one calibration curve can suffice for

all background brightnesses within the calibration range.

A *visibility index* number has the following meaning: It is a number equal to the contrast of an equivalent gray disc on a uniform background and indicates that the object has a supra-threshold visibility equivalent to the gray disc; the physical conditions of size, reflectance and brightness for the calibration disc being as previously described. The parameters of time, motion, color and critical detail are excluded and are not evaluated by the instrument. Thus a visibility index dial reading of 30 indicates that the scene has the same supra-threshold visibility as a gray disc on a gray background having a contrast of −16 per cent (a Visibility Index of 16) whereas a Visibility Index dial reading of 70 indicates the same visibility as a disc having a contrast of −82 per cent and therefore a visibility index of 82. (See Fig. 7.) The calibration curve is a function of the transmission characteristics of the partial mirror but the visibility index is independent of the mirror transmittance by virtue of the calibration procedure.

Street Lighting Laboratory

A section of roadway within the area of the Engineering Field Station of the University of California at Richmond, California has been assigned for experimental street lighting studies. The area is 55 x 450 feet and is graded and paved with a blacktop macadam surface. See Fig. 8. A row of poles 35 feet high on 50-ft centers has been erected along each side. Mast arms, power, circuits and controls have been developed to permit almost any combination of lighting equipment to be operated. A layout of the roadway and pole location is shown in Fig. 9.

Two basic lighting situations have been under investigation as the first phase of our research: (1) wherein pavement brightness is approximately uniform and (2) in which the pavement brightness

Figure 8. Daytime scene of outdoor Street Lighting Laboratory at University of California Engineering Field Station, Richmond, Calif.

is markedly non-uniform. Several combinations of modified luminaires have been used to secure these patterns but none of the patterns have been obtained with standard commercial street lighting luminaires. The uniform patterns have varied in brightness ratio from 4:1 to 1.1:1 and the non-uniform patterns have had ratios of 12:1 to 36:1 over the test area. Two typical pavement brightness patterns are shown in Fig. 10. The illumination and brightness data for these conditions are shown in the iso-lux and iso-brightness diagrams in Progress Report No. 2 I.E.S. Research Project No. 37.[4]

Preliminary Results of Visibility Measurements

Several sets of test data have been reported in previous test reports rendered to the I.E.S. Research Fund.[4] The results to be presented here are a summary of previous work.

Among the problems that arise in connection with visibility measurements is the matter of target design and location. It has become apparent that the type of target is extremely important and can influence the results to an appreciable degree. For

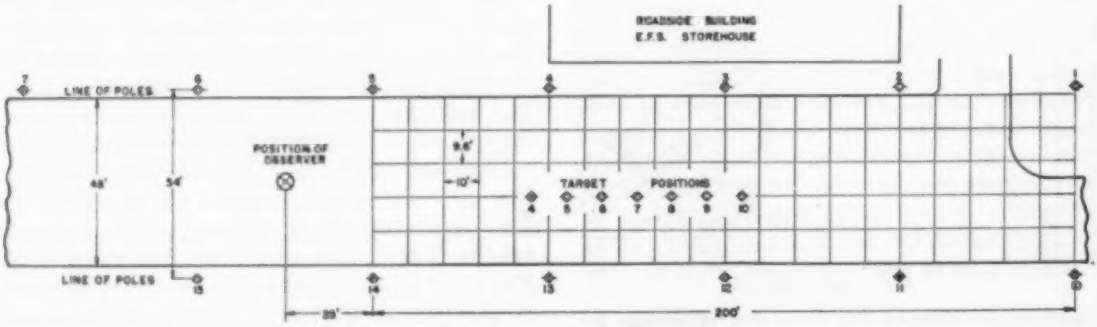

Figure 9. Plan view, street lighting test area.

instance, if a small round disc one foot in diameter is used as a target as in several research investigations by others[5] one may find many locations on a lighted roadway with either uniform or non-uniform brightness where the target brightness will equal the background brightness and the visibility will be very low. If one changes the plane surface to one having multiple plane segments, the number of low visibility target positions on the roadway will be reduced. If one uses a larger target or a tall narrow target to simulate a pedestrian still different visibility indices will result. It is desirable from a research point of view to reduce the number of targets and to have them representative of field conditions and at the same time each should present a reasonably difficult visual task so that differences in the lighting systems will show up in the measurements.

All roadway lighting systems now in current use are directional in principle and practically all roadway obstacles are three dimensional in form, therefore the target should take these conditions into account. These considerations suggest a three dimensional target so that brightness variations will occur within its boundaries but each patch of brightness on the target must be of sufficient size to be observed as an area for contrast discrimination. At roadway sight distances of 75 to 500 feet the target therefore should have a minimum dimension of approximately 6 in. for any segment and should have at least three vertical planes with approximately equal projected dimensions. This would result in a target with a minimum projected width or height of approximately 18 inches. Due to the overhead mounting of most luminaires it is also important to consider the downward directed component of light and therefore to have some surfaces on the target oriented in non-vertical planes to reveal this characteristic of the lighting system. Examples of the above effects are demonstrated in the photographs of Fig. 11 to 13. Note that in Fig. 11a the pavement brightness is approximately uniform and the targets are seen against very nearly the same background brightness. At this position and for the target surface reflectance of 10 per cent, the vertical faces have a very low brightness whereas the inclined faces on the multi-plane target (octagonal-section) all have higher brightnesses. These differences result in variations in the visibility index as will be discussed later. In this case the plane disc has the higher over-all contrast and therefore has a higher visibility index than the octagonal-section target. (See Table I.)

The three-dimensional effect is further emphasized in Fig. 13b where the same two targets are viewed against a non-uniform pavement brightness pattern. In this case the vertical planes are very dark and the background brightness is low so the contrast is very poor but the inclined planes on the left side of the octagonal-section of this target develop considerable brightness and thereby raise the over-all contrast of this target well above threshold. The visibility indices shown in Table I reflect this situation. For this visual situation the octagonal-section target has a moderately high visibility index whereas the plane disc reads zero.

The target designs that we have used for these studies are shown in Fig. 14. At a recent meeting of the advisory committee for this project (May 1956) the effect of target shape and size was discussed and the conflicting requirements were reviewed. It was proposed that the targets should be

TABLE I — Visibility Measurements Using Uniform and Non-Uniform Pavement Brightness. (Glare effect of luminaires is excluded — field of instrument does not include the light sources)

	Uniform Pavement Illumination (1.3:1 variation)		Non-Uniform Pavement Illumination (19:1 variation)		
Object Position (See Fig. 7)	Pavement Brightness = 0.20 ftL. Br. Ratio = 4:1 in test area		Pavement Brightness = 0.35 ft-L. max. 0.03 ft-L. min. Br. Ratio = 12:1 in test area		Direct or Silhouette Seeing
	Type of Object		Type of Object		
	Circular Disc	Octagonal Sec.	Circular Disc	Octagonal Sec.	
	Vis. Index	Vis. Index	Vis. Index	Vis. Index	
4	39				Silhouette
4		28.5			Silhouette
4			0		
4				0	
5	39				Silhouette
5		31			Silhouette
5			10		¼ Silhouette
5				15	¼ Silhouette
6	39				Silhouette
6		34			Silhouette
6			30		¾ Silhouette
6				32.5	¾ Silhouette
7	39				Silhouette
7		42.5			Silhouette
7			45		Silhouette
7				51	Silhouette
8	40				Silhouette
8		48			Silhouette
8			45		Silhouette
8				51	Silhouette
9	43.5				Silhouette
9		43.5			Silhouette
9			41		½ Silhouette
9				51	½ Silhouette and Direct
10	39				Silhouette
10		40			Silhouette
10			0		
10				44	Direct

Figure 10a. Uniform roadway brightness pattern. No targets. 4:1 brightness ratio within target area.

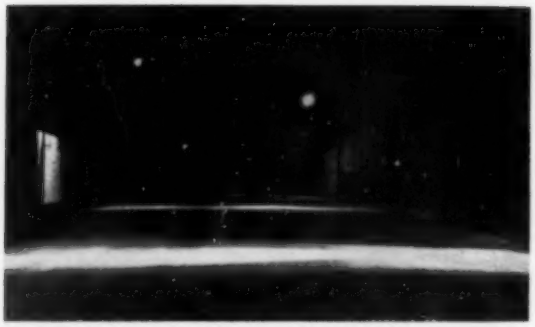

Figure 10b. Non-uniform roadway brightness pattern. No targets. 12:1 brightness ratio within target area.

Figure 11a. Uniform roadway brightness pattern. Targets at Position 4.

Figure 11b. Non-uniform roadway brightness pattern. Targets at Position 4. (Pinpoint of light indicates target position.)

Figure 12a. Uniform roadway brightness pattern. Targets at Position 8.

Figure 12b. Non-uniform roadway brightness pattern. Targets at Position 8.

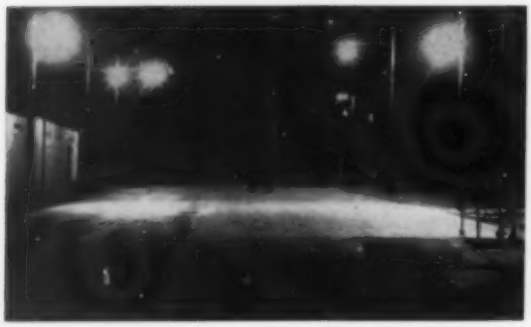

Figure 13a. Uniform roadway brightness pattern. Targets at Position 10.

Figure 13b. Non-uniform roadway brightness pattern. Targets at Position 10.

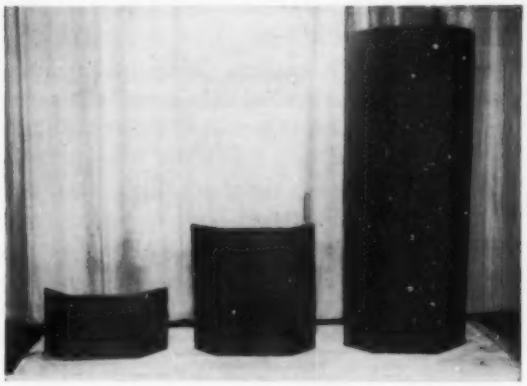

Figure 14. Roadway targets. (above) 18-inch plane disc, partial octagonal-section, full octagonal-section targets; (right) 3-sided vertical plane targets suggested by Illuminating Engineering Research Institute Committee.

standardized in cross-section but in a range of three heights. The proposed shape is a three sided section of a right rectangular prism with one normal and two 45-degree vertical planes each one foot wide and in three heights of 1, 2 and 5 feet. Photographs of sample targets conforming to these sizes and having 10 per cent reflectance are shown in Fig. 14.

Some preliminary studies on the proposed three-sided vertical plane targets indicate the need for inclined top surfaces to reveal the downward component characteristics of some lighting systems. Preliminary data also show that there may be a marked difference between the visibility of a short or a tall object under non-uniform pavement brightness conditions. These data are not complete and are not yet available in numerical form. They seem to indicate that as many as three targets may have to be used in a complete visibility evaluation to reveal different lighting characteristics. These three types of targets are: (1) a small plane diffusely reflecting surface (18 x 18 inches, square or round), (2) a small multi-plane object (three vertical planes with three 45-degree sloping planes — 18 x 18 inches) and (3) a tall multi-plane object (same as (2) except 18 x 60 inches). With three such objects each with a low reflectance (10 per cent) matte surface and placed at various locations within a representative roadway brightness pattern, visibility index measurements can be made which can then be used to make an over-all evaluation. The small plane target would simulate holes or cavities in the roadway and objects having completely diffuse reflectance properties to make them appear uniformly bright, the small multi-plane target would simulate most small obstacles above the roadway (boulders, boxes, small animals, etc.) and the tall- narrow, multi-plane target would simulate pedestrians and other larger targets. For example, in the experiments made upon the two pavement brightness patterns previously described we observed the following data for the round plane disc and the octagonal-section targets located at position Nos. 4 to 10 (70 to 130 ft) on the test roadway. See Fig. 9. Photographs of targets at positions 4, 8 and 10 for the uniform and non-uniform patterns are shown in Figs. 11 to 13. The visibility index numbers do not include any glare effect that may be present due to the light sources. The field of view of the present instrument is not large enough to include the light sources used for these measurements. These data bring out the following points:

(1) With the uniform pavement brightness lighting system developed especially for these tests the plane disc was always seen in silhouette (negative contrast) and had moderately high visibility indices that were nearly the same for all positions along a central line ahead of the observer.

(2) With the uniform pavement brightness lighting system the octagonal-section target revealed considerably greater variation in visibility due to the directional nature of the light. At some positions (No. 4 as an example) the direct light on the inclined planes caused their brightness to be higher than that of the vertical normal plane and thereby reduced the over-all contrast with the background. The resulting visibility index for the octagonal-section target was therefore lower than for the plane disc target at this location. At position No. 8 the octagonal-section target gave a somewhat higher visibility index than the plane disc because the average brightness of the disc was higher than the average brightness of the multi-plane target. This is caused by the directional reflectance characteristics of the target surfaces.

A logical conclusion would be that under this system of lighting which developed approximately uniform pavement brightness the target shape had only a small effect upon visibility, but it is apparent that the three-dimensional target provides more information about the visual conditions than does the plane disc target.

(3) The non-uniform roadway brightness pattern was next developed upon the same area of the experimental roadway. The same targets were placed in the same locations as for the uniform brightness pattern tests. The variation in brightness was such that for certain locations the targets were seen against a very low background brightness and at other positions against a much higher background brightness. The average roadway brightness for the non-uniform pattern was approximately the same as for the uniform pattern.

The visibility index numbers for both the plane disc and the octagonal-section target are given in Table I. Note that in many of the positions the targets are seen partly in silhouette (negative contrast) and partly by direct lighting (positive contrast).

Within the non-uniform pattern both the plane disc and the octagonal-section vary in visibility from zero to moderately high values. There are more locations where the plane disc target has low visibility than for the three-dimensional target (see position Nos. 4 and 10).

The three-dimensional target more nearly approximates roadway seeing conditions for small objects under the non-uniform brightness patterns. Such patterns are only developen by highly directional lighting systems and three-dimensional targets can give an indication of such directionality in many instances that would not be demonstrated by a plane target.

Another set of field data is being analyzed at present in which a different uniform brightness pattern has been employed which has closer spacing of sources with more downlighting. Also a greater observation distance has been used. Although the final calculations are not now available the results appear to check those reported herein and the same conclusions regarding target visibility are emerging. There seems to be the need for more than one type of target.

Summary and Conclusions

The principle of operation of the contrast-threshold visibility instrument described in this report has been successfully demonstrated. It is believed that within the design limitations that are given, the meter can be used to obtain reliable visibility evaluations. The numerical number used to evaluate a specific situation is termed the Visibility Index.

The visibility indices are given for several types of targets (plane, two-dimensional and multi-plane, three-dimensional) for two experimental roadway lighting systems which develop uniform and non-uniform pavement brightness patterns. The system developing the uniform pavement brightness has a large number of sources and is less directional than the system developing the non-uniform pattern.

The directional effect of the lighting is evident when a three-dimensional target is used under either the uniform or the non-uniform system. Much greater variations in visibility were observed with the non-uniform brightness pattern than with the uniform pattern.

For extremely non-uniform patterns and small targets it is possible to lose the target in the dark area between the bright patches. The plane disc targets are lost more frequently than the multi-plane targets.

For uniform patterns that are developed with relatively few sources having appreciable directional distributions it has been observed that a plane disc target may disappear (drop below threshold) at somes test locations even though the background brightness is relatively high. This is due to the direct light on the front of the target which develops a uniform target brightness approximately equal to the background. Such an effect does not usually occur for multi-plane targets because the target brightness is never uniform. (It might occur with high reflectance objects.)

Tall thin targets simulating a pedestrian are now being evaluated. The preliminary data indicate that for both uniform and non-uniform pavement brightness patterns the visibility indices do not vary nearly as much as for the shorter targets when the target is moved from place to place within the test area. This is due to the fact that some part of the target develops a supra-threshold contrast with its background at almost every roadway position even though the over-all contrast of the target may be lowered because a portion of the target is at threshold contrast.

The role of roadway brightness pattern and target size and shape in the night visibility of road-

way obstacles is demonstrated for two conditions which may be considered the extremes of engineering practice.

It is apparent that the final pavement brightness pattern is important, but also the lighting system used to obtain this pattern is equally significant.

No one target seems to be adequate for a complete field evaluation of visual conditions. Probably a minimum of three targets should be used for visibility measurements: (1) a small plane area, (2) a small multi-plane surface, and (3) a tall multi-plane surface. These should cover most critical seeing situations and permit a fair appraisal to be made for static visual conditions.

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DISCUSSION

W. B. ELMER:* The new visibility meter is a most important and significant development giving promise when the wide field instrument is build of determining definitively the relative visibility of different lighting systems and luminaires.

This recent work with larger and three-dimensional targets is beginning to give significant night-time visibility data for the first time and makes former work with small flat targets relatively insignificant.

Page 127, Point 1 states that the uniform pavement brightness system gave moderately high visibility for all positions. If the target were of higher reflectance, it would be less visible. *Some reflectance values might make the targets generally invisible throughout,* under uniform pavement brightnesses. Some controlled non-uniformity could give better overall visibility.

No general conclusion that maximum uniformity of pavement brightness gives maximum visibility is warranted. It appears from theoretical considerations and test results to date that a street lighting system giving controlled non-uniformity will provide the greatest overall visibility.

K. M. REID and D. A. TOENJES:** The author reports interesting and ingenious improvements in the design and construction of his visibility meter. Undoubtedly it will prove to be valuable in field studies of the relative seeing effectiveness of various street lighting installations. Is it now in form suitable for use by other investigators? And are any plans under way toward manufacture of these meters?

The paper points out that the existing meter does not yet have a large enough visual field to include the glare effect of the street lighting units. Therefore, the visibility scale refers to conditions in which the street lighting luminaires are shielded from the field of view. The paper further states that the total field of view of the present instrument is about 15 degrees and the central field of view is 2 degrees, while with future models it is expected that the total field of view will be about 30 degrees, with the same central field. Are we correct that a total field of view of 30 degrees means 15 degrees displacement from the line of sight? Is this field of view circular in shape?

It will be interesting to compare the instrument's field of view with that of the motorist in the average passenger car. Our information on this point is not fully up to date, because it was obtained in 1951 from the Michigan State Highway Department and the U. S. Bureau of Public Roads, in connection with pavement reflectance measurements. However, the average age of automobiles on the road today in this country is about six years, so the windshield cut-off angles represented here are close to average for cars now in use. The vertical angles were about 12 degrees above horizontal, with reference to the average driver's eye position, and within the range of 13-22 degrees below horizontal, depending upon the size of the car. This gives a total vertical angle of 25 to 34 degrees. The horizontal angle, with reference to a line of sight directly ahead of the motorist, is about 58 degrees to the right and 23 degrees to the left, or a total of about 81 degrees. The driver's eye level is at an average of about 54 inches above the pavement. Thus it appears that a proposed later instrument with a total field of about 32 degrees would be reasonably well in line with the vertical angles that the motorist can see through a typical windshield. It is the vertical angle of cut-off that generally determines whether or not the street lighting luminaires are in the field of view.

We believe that a preferred instrument design, however, would be one in which the field of view, including the field of pickup of veiling glare, is substantially greater. Then, when measurements are made, as they preferably are, from the driver's seat in a car the cut-offs actually provided by the car serve to limit the field. Such a wide field would expand the flexibility of use of the instrument. It could then be used in measurements, not only for the average driver in the average car, but also for variations in car design and variations in position of the driver's eyes.

C. H. REX:* Professor Finch is certainly to be commended for his interest in roadway lighting and for his progress report on the difficult night work he has been conducting at Berkeley, Calif. It is hoped that his facilities and staff for the evaluation of roadway lighting principles, technique and effectiveness will be expanded considerably.

Much more needs to be done at a greatly accelerated pace, appropriate to the importance of lighting, in improving night travel conditions so that the multi-billion dollar motor vehicle transportation business will, in the future, be more efficiently kept open after dark.

The Technical Advisory Group of the Illuminating Engineering Research Institute has recommended an assessment appraisal of seeing under three conditions: (a) good roadway lighting, (b) poor roadway lighting, (c) no roadway lighting.

Numerical ratings for good roadway lighting should come first. The lighting should be representative of current recommended practice using modern luminaires and spacings comparable to Table V of the American Standard Practice.

*Wheeler Reflector Co., Boston, Mass.
**Application Engineering Dept., Lamp Division, General Electric Co., Cleveland, Ohio.
*Outdoor Lighting Dept., General Electric Co., Henderson, N. C.

As is known, such lighting generally provides pavement brightness uniformity equal or better than that designated as uniform by Professor Finch. The lighting by which Professor Finch produced non-uniform pavement brightness is certainly poor lighting.

As Professor Finch says, under uniform pavement brightness a plane disc target is usually seen in silhouette. He also says, "We will probably never run out of variables to investigate" and "One quantity that seems to be the key to the entire problem is the roadway brightness as seen by the vehicle operator."

So it is hoped further studies will indicate that three different obstacle brightness targets *will not* be necessary for the evaluation of the relative effectiveness of roadway lighting systems.

We are confident that simplification will result. His data probably indicate which facet of the three-dimensional target is resulting in the predominant contrast discernment at each representative roadway station. Or separate targets may be used for a series of complete relative visibility measurements with the purpose of weeding out those not essential for field testing.

We are looking forward to the availability and correlation of his new instrumentation.

D. M. FINCH:* The comments of these discussions are appreciated and bring out several points that either were not covered adequately in the paper or that cannot be answered as yet because of insufficient data.

Mr. Elmer draws his own conclusions from the data presented that a system giving controlled non-uniformity of pavement brightness would provide the greatest overall visibility. I believe that this is a premature conclusion, at least based upon the data of this paper. We have had as one of our objectives the identification and evaluation of some of the factors in the night-time roadway visibility problem. Pavement brightness and its distribution is certainly one of the important factors. Just how this factor should be controlled for best visual conditions is still far from being solved. Each particular roadway function such as continuous section, intersection, ramp, curve, etc., will probably have its own characteristics and specifications, insofar as roadway brightness is concerned.

The importance of target size and shape is beginning to be evident. Most targets are composites of many surfaces, reflectances and spectral distributions of flux. For our preliminary work we will have to reduce the number of variables to a minimum. Therefore, for some studies we may still wish to use small two-dimensional targets but for most cases we will probably wish to use small three-dimensional targets.

Messrs. Reid and Toenjes are correct in their interpretation of the field of view of the instrument. The present field is conical in shape with a total plane angle of approximately 15 degrees. Our present plans call for a modification to yield approximately 30 degrees total plane angle. A larger field is much to be desired but we have not solved the optical problems for a still larger field. We too have determined that a 25- to 35-degree field will be within the normal range of vertical angles encountered in motor vehicle visibility problems. This seems to be a practical compromise in design.

At the present time we do not have any plans to have the instruments manufactured although drawings are available for anyone who may wish to construct an instrument for his own use.

Mr. Rex has pointed to the increasing need for studies of roadway lighting. We firmly support his arguments in that it appears to us that roadway lighting is one of the most important, but so far least used, tools of the roadway designer in creating a safer and more efficient structure. The reason for its being least used is that it is probably least understood. We can do much to change this situation by research on the important quantities such as pavement brightness patterns, glare effects and reduction of conflicting and distracting visual areas in the field of view.

It may be that a uniform and simplified technique for roadway lighting evaluation will evolve in which it will not be necessary to use three or more targets. We have not yet reached that stage. Until we have most of the parameters isolated we will not be able to definitely say which target is more important. We are hopeful that continued support for the research will be forthcoming and that answers to some of the pressing problems will gradually evolve.

*Author.

Exercise your privilege to vote . . .

in the election of National and Local I.E.S. Officers and on other Society changes. Your ballots will be reaching you early in April.

INSTALLATION AT TAIT MOTORS, LINCOLN HIGHWAY EAST, COATESVILLE, PA.

Lighting an Automobile Repair Shop

LIGHTING OBJECTIVE: To provide high level lighting for both bench repairs and general automobile servicing.

GENERAL INFORMATION: This repair shop, which has space for servicing seven automobiles at one time, measures approximately 29 feet 6 inches by 86 feet. The ceiling height is 15 feet 9 inches. Bench repair work is performed along the rear wall. Surface colors and reflectances are as follows:

Ceiling	unpainted concrete and steel beams	15% RF
Walls		
Upper ⅔	white	57% RF
Lower ⅓	gray	24% RF
Floor	unpainted concrete	12% RF

INSTALLATION: Twenty-six Benjamin catalog No. 96102 porcelain enamel reflector industrial fluorescent units, suspended 5 feet from the ceiling on chain hangers, illuminate the entire repair shop. Nine of these located along the rear wall (as shown in Fig. 2) provide illumination for bench repairs. Each unit is equipped with two 96-inch T12 standard cool white slimline fluorescent lamps.

(over)

A.I.A. File No. 31-f

After 300 burning hours the illumination was 60 footcandles in the general service area and 75 footcandles in the bench repair area.

Brightnesses at that time were as follows:

Luminaires	
at 13° cutoff	450 ft-L (approx.)
Ceiling	8 ft-L
Walls	
Upper	2.3 ft-L
Middle	19.9 ft-L
Lower	8.4 ft-L
Floor	.96 ft-L

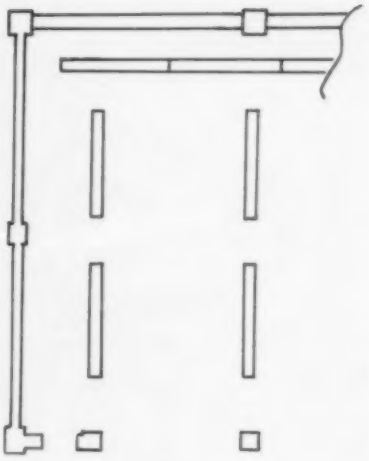

Figure 2.

Lighting designed by Michael N. Flynn, District Representative, Benjamin Electric Mfg. Co., and S. W. Purdum, Lighting Engineer, Philadelphia Electric Co.; General Contractor, C. Timothy Slack, 129 South 5th Ave., Coatesville, Pa.; Electrical Contractor, C. & W. Electric Co., Coatesville, Pa.

Lighting data submitted by George T. Anderson, Jr., Lighting Engineer, Philadelphia Electric Co., 211 So. Broad St., Philadelphia, Pa., as an illustration of good lighting practice and to aid in the design of similar installations.

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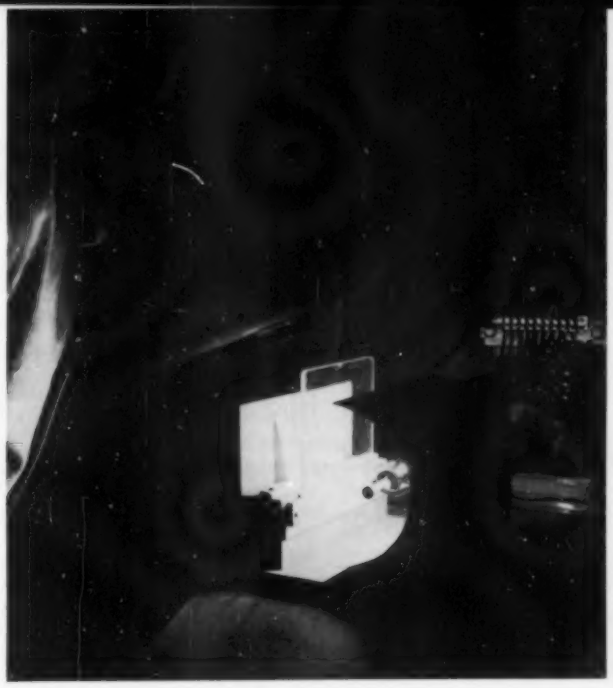


Light stability test in action

An answer to the problem of discoloration of polystyrene used for fluorescent luminaires has long been sought by the plastics industry. Presented here is a brief review of research and development work aimed toward light stability of this material.

Discoloration of Polystyrene Shields: Its Cause and Solution

By JOHN B. ORR

PLASTICS for shielding purposes have for some years had a prominent part in luminaire design. Factors high in its favor have been its light weight, ease of handling and cleaning, good appearance, and excellent diffusion characteristics. A disappointing characteristic, however, has been its tendency to yellow, sometimes rather quickly. Greater light stability has been a major development goal.

Before any progress could be made toward the solution of this problem, it was necessary to identify the cause of the discoloration. Observation of polystyrene plastic panels which had been installed in fluorescent luminaires for a number of years indicated that the plastic material had a tendency to turn yellow on the sides of the panels adjacent to the light source. Further, the yellowing was more intense in the areas closest to the fluorescent tubes. Such yellowing became noticeable in 5,000 to 15,000 operating hours, for most fluorescent luminaires.

Ultraviolet radiation causes polymerization of styrene monomer, as has long been known. Molded or extruded polystyrene exposed to direct sunlight will discolor and craze relatively quickly, usually in less than a year. On the other hand, yellowing of polystyrene is rarely observed in indoor applications removed from fluorescent sources. This is the case even where sunlight falls on the plastic, providing the sunlight has been filtered by passing through ordinary window glass. Since most of the ultraviolet below 3900 Å is absorbed by the glass, the obvious conclusion is that ultraviolet of some lower wavelength, emitted by fluorescent lamps, is a factor in the yellowing of polystyrene. It is quite possible that many complex reactions of a photochemical nature may take place when polystyrene is exposed to ultraviolet radiation. There is evidance that such reactions are not merely toward the formation of higher weight polymers. There may be oxidation and/or cross linkage of the styrene polymers. It is of interest in this connection, to note that the reaction is not just a surface one, but that the discoloration is apparently proportional to the intensity of ultraviolet radiation throughout the thickness of the polystyrene material.

AUTHOR: Manager, Technical Service, Sheffield Plastics Inc., Sheffield, Mass.

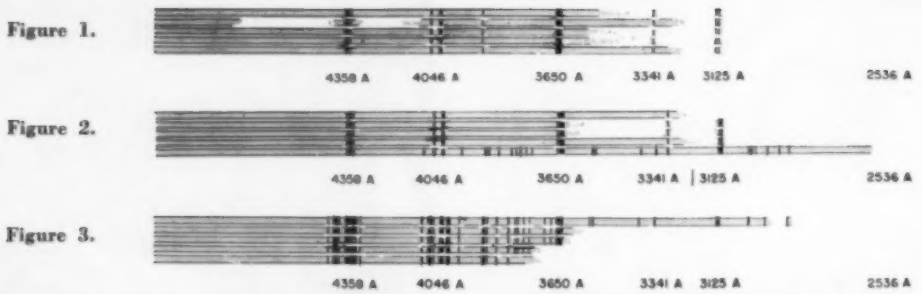


Figure 1. Top to bottom: 1—cool white standard, 2—special, 3—cool white, 4—daylight, 5—warm white de luxe.
Figure 2. Top to bottom: 6—cool white de luxe, 7—warm white standard, 8—white,9—soft white, 10—mercury are with 9700 filter.
Figure 3. Top to bottom: regular polystyrene, 10%, 15%, 20%, 25% UVR polystyrene. (Light source, G-E sunlamp.)

In addition, it was noted that the yellow material so formed tends to separate from the plastic material and can in fact be partially removed from the surface by rubbing with a damp cloth. A clean handkerchief, for example, slightly dampened will show a yellow stain when rubbed over the surface of irradiated polystyrene.

The effect of direct sunlight on polystyrene described above offers a clue to the range of ultraviolet light which is effective in the photochemical reaction. The absorption of light by the earth's atmosphere cuts off most of the ultraviolet from the sun below 3000 angstroms. The cut-off point for ordinary window glass, however, is at about 3900 angstroms or just below the range visible to the normal human eye. It seems reasonable to conclude, therefore, that ultraviolet radiation in the range of 3000 to 3900Å is photochemically active in the yellowing problem. Theoretically, any photochemical reaction should be cumulative. That is, there should be a fixed probability that a certain percentage of the photons of light of each wavelength striking the plastic surface will react photochemically to produce yellowing. The degree of yellowness will, therefore, depend on the total number of photons of each wavelength which fall on the plastic. Whether this number of photons requires several years or several days to accumulate should be immaterial. The wavelength of the radiations is, however, of prime importance, since the probability of the photochemical reaction will be dependent on such wavelength.

In measured tests, variations were observed in the degree of yellowing of panels made of the same batch of plastic but exposed to different types of fluorescent lamps. It seemed probable, therefore, that there was a variation in the spectral emission not only of different types of fluorescent tubes, but in the same type tube made by different manufacturers. Accordingly, spectro analyses were made of the common types of tubes made by leading manufacturers.

Figs. 1 and 2 illustrate the spectral emission of various types of tubes over the range from 2500 to 4500 angstroms. A study of these reveals that the emission is that given off by a mercury discharge with some continuous spectrum extending above 3650Å in the cases of spectra 7 and 8, from 3500Å and above in the cases of spectra 1, 3 and 4 and from 3200Å and above in the cases of spectra 2, 5, 6, and 9.

The presence of mercury is natural, since most fluorescent tubes depend on its presence for their proper operation. The continuous spectra, seen in Figs. 1 and 2 are visible light emitted by the fluorescent coating on the inside of the tube.

All of the fluorescent tubes examined emit radiations in the damaging range from 3000 to 3900Å. The lamps shown in spectra 2, 5, 6 and 9 appear to be almost twice as active in this range as those shown in spectra 7 and 8.

Accelerated Test Method

In investigating this problem of yellowing, it seemed imperative to devise some accelerated test method for determining the value of the various ideas which presented themselves as possible solutions. With the spectral analysis of fluorescent tubes in mind, a test method was devised in which samples of extruded shields could be exposed to a highly concentrated light source similar in spectrum to that of a standard white fluorescent lamp. A Hanovia Chemical Company 550-watt high pressure mercury discharge tube with a quartz envelope was selected as the light source. This envelope is transparent to all light from 2000 to beyond 7000Å. In order to limit its radiation to the 3000 to 6000Å range of a standard white fluorescent lamp, a Corning glass filter #9700 was placed between the

lamp and the samples. This filter transmits the visible light above 4000 Å as well as the ultraviolet down to 3000 Å. The cut-off point is quite sharp, so that most of the 3125 Å line is transmitted, but almost nothing below 2967 Å passes through. The spectra of this light source with filter is illustrated in Fig. 2, spectrum 10 for comparison purposes.

In the test, samples are mounted on a revolving table so that all received an equal amount of radiation. In addition, since mercury discharge tubes age with time, and the light output decreases considerably in the course of 2000 or 3000 hours of operation, a standard specimen of known performance was included in each test run. A comparison of all unknown samples with a known standard was thus possible.

Since considerable heat is also emitted by this source, it was thought advisable to cool the test samples with a stream of air, so that the temperature of the plastic samples did not exceed 120 F. This air stream had to be carefully directed to avoid striking the quartz envelope of the light source, since the intensity of the discharge is highly temperature-dependent.

To further maintain the consistency and accuracy of the test, the mercury discharge lamp is replaced every 2000 hours.

In order to determine the rate of acceleration of the test, polystyrene panels with known histories in fluorescent fixtures were obtained. Wherever possible a sample of such a panel, taken from a section which had been shielded from the fluorescent light by metal parts of the fixture, was subjected to the accelerated test apparatus. In this way it was determined that one hour under the quartz discharge tube at a distance of four inches from the light source equals approximately 350 hours in a fluorescent fixture at a distance of one inch from a standard white lamp at its center.

Secondary Benefits Realized

Although the main objective in the research program was the development of shields with greatly improved light stability, some secondary benefits were realized from this development program. During the early part of the work, as an example, it was discovered that there was considerable variation in the light stability of identical panels made with different batches of polystyrene supplied by any one manufacturer. Repetitive tests enabled the selection of panels having the greatest light stability. These were maintained in a light-proof vault.

As each new batch of polystyrene was received, sample panels were extruded and sections of these, together with a section of one of the master samples, were exposed in the accelerated light test. In this way, quality control procedures were set up for all material intended for processing into lighting fixture panels. Material manufacturers cooperated in this effort so that only the most stable lots of polystyrene were used. As a result, it was possible to minimize variations in the light stability of the shields and to improve their quality. Further tests revealed that certain heat resistant types of polystyrene resist discoloration up to 70 per cent longer than regular extrusion grades. Consequently, such material used almost exclusively for shields, could further improve the quality.

Injection molded polystyrene samples were also tested. These appeared to be considerably less resistant than extruded polystyrene. We presume, therefore, that styrene monomer is quite deleterious and reacts photochemically with polymerized molecules. (See Table I.)

TABLE I.

Sample	Test Hours to Reach Standard Yellowing Point
Regular extrusion grade polystyrene	20.0
Heat resistant polystyrene	49.25
"Light stable" polystyrene	68.5
10% "UVR" polystyrene	184.0
15% "UVR" polystyrene	200.0
20% "UVR" polystyrene	225.0
25% "UVR" polystyrene	225.0

Development of Light Stable Polystyrene

Of several ideas considered in the search for a light stable material, the one which seemed to offer the most promise was the possible inclusion in the plastic of some material which would preferentially react with the ultraviolet radiation to reduce the photochemical reaction with the plastic. There were a number of ultraviolet absorbing materials available, but one had to be found which could be combined with polystyrene successfully and yet would not affect the extrusion characteristics or physical properties of the plastic.

Subsequently a suggestion was made by a research worker outside our organization that the effectiveness of an ultraviolet absorber would be much enhanced if it could be concentrated near the surface of the plastic panel on the side adjacent to the light source. Our work had revealed that yellowing begins on the side nearest the light source. We had also found that yellowing of even 0.010 inch of the inside surface of a panel was noticeable through the plastic. Hence, an even dispersion of ultraviolet absorbing material throughout the panel would be of little value if yellowing took place on one surface.

Further, we knew that it was theoretically impossible to prevent all ultraviolet light from passing into the panel. However, if 90 per cent of the ultraviolet radiation could be absorbed in the first 0.010 inch of the plastic, there was little point in absorbing more in the balance of the panel. This approach obviously offered an opportunity to develop panels with the greatest light stability at the lowest cost. The research program, therefore, was aimed at the development of an ultraviolet absorbing material which could be concentrated on the side of the panel adjacent to the light source. Obviously, the main problems were the selection of an efficient absorber and the development of a method for permanently combining it with the plastic.

Samples of shields developed as a result of this study were subjected to the accelerated aging test. Such shields have exhibited up to six times the light stability of shields made with regular extrusion grade polystyrene. Included in Table I are the results of irradiating regular extrusion grade, the heat resistant type and the most stable of the new light stable polystyrenes now available.

The amount of ultraviolet absorbing material combined with the plastic has a marked effect on its light stability. This explains the variations in light stability of the various uv-absorbing samples listed in Table I.

In Fig. 3, spectrographs are shown of light from a G-E sunlamp transmitted through samples with various concentrations of ultraviolet absorber incorporated in the plastic near one surface only. It can be seen that regular polystyrene, without any ultraviolet absorber, transmits readily all light to below 3000 Å. Polystyrene containing a 10 per cent concentration of uv absorber on one surface transmits nothing below 3650 Å and only about one-half of the 3650 Å band. Higher concentrations of uv absorber cut out more and more of the 3650 Å band until at 25 per cent absorber almost all of the light below 3750 Å is absorbed.

The light stabilities of samples whose spectra are shown in Fig. 3 are illustrated in Table I. It is apparent from Table I and Fig. 3 that the photochemical reaction producing yellowness in polystyrene is confined to ultraviolet light of less than 4050 Å wavelength.

Once a method was developed for permanently combining the ultraviolet absorbing material with the plastic, there remained the problem of developing a method for consistent control of the degree of light stability of all panels produced. Note in Fig. 3 that the 3650 Å mercury line is common to all the samples. This suggests a sensitive means of measuring the effectiveness of an ultraviolet absorber. Following this reasoning, we had an independent laboratory design and build apparatus which enables us continuously to measure the transmission of light from the 3650 Å mercury line through the "UVR" grade material during production. All panels having greater ultraviolet transmission than a predetermined amount are rejected.

TABLE II.

Manufacturer	Type Lamp	Ultraviolet Emission
Sylvania	Cool white standard	1.0
A	White	1.0
A	Warm white standard	1.0
A	Cool white	1.14
A	Daylight	1.17
A	Cool white de luxe	1.78
A	Warm white de luxe	2.07
A	Soft white	2.26
B	Cool white standard	1.0
B	Warm white standard	1.0
B	White	1.0
B	Daylight	1.3
B	Cool white de luxe	2.1
B	Warm white de luxe	2.56
B	Soft white	2.6
C	White	1.0
C	Warm white standard	1.0
C	Daylight	1.62
C	Cool white de luxe	2.23
C	Soft white	2.44
C	Warm white de luxe	2.5

UV Emission of Various Fluorescent Lamps

In view of the variations of the spectra of various tubes shown in Figs. 1 and 2, it seemed of interest to evaluate the total emission below 4000 Å of as many fluorescent tubes as were available. To do this, a photo tube was obtained which, with proper filters, would measure the total light given off by fluorescent tubes below 4000 Å and which would have a nearly flat response at all wavelengths.

Table II shows measurements obtained with this apparatus on a large number of commonly available fluorescent tubes. The emission of a Sylvania "cool white standard" is taken as 1. All other values are shown in terms of or as multiples of this standard.

It is evident from the data in Table II that careful consideration should be given to the type of tube to be used in each installation where plastics shields or pans are involved. As newer and higher wattage lamps are developed, the yellowing problem will become more and more important to the lighting engineer and thus to the lighting panel manufacturer.

Conclusion

With the development of the ultraviolet-absorbing shields, it appears that lighting engineers and designers will now be able to consider the use of polystyrene plastics for shielding fluorescent lamps in many applications otherwise reserved for other materials.

A New Approach to Highway Tunnel Lighting

By JOHN R. BRASS
HAROLD SKOOTSKY
GILBERT A. TROSPER

UP TO THE END of World War II, tunnel construction was avoided as much as possible because it was cheaper to build around a mountain than through it. But today, with the emphasis on an efficient transportation system, highway user savings in operating costs will often justify the more costly tunnel construction.

The illumination of tunnels has progressed from practically no lighting to quite high levels, as will be reported later. As new light sources were developed, engineers tried them out in tunnels and, generally, each new installation provided better visbility than the last.

In the San Francisco Bay Area several tunnels have been built during the last sixty years. Some of them are:

Stockton Street Tunnel, San Francisco: This tunnel, built in 1914 is 914 feet, portal to portal. Side walls are tiled 8 feet high; the balance of the walls and ceiling are concrete finished. The original lighting consisted of two rows of 100-watt incandescent lamps in RLM reflectors, on 26-foot centers. Roadway illumination averaged approximately 0.2 footcandle.

In 1930 the 100-watt lamps were changed to 150-watt with almost 100 per cent increased illumination over the original lighting. In 1933 the incandescent lighting was again changed and nineteen 10,000-lumen sodium units were installed. Again, the roadway illumination was greatly improved, averaging better than 0.83 footcandle. In 1950 two continuous rows of single-lamp open fluorescent fixtures with standard cool white lamps were installed. These 200 bare lamps, operating at 425 ma, provided an initial average roadway illumination of about 10 footcandles.

Posey Tube, Alameda: An underwater tube built under the Oakland Estuary to Alameda in 1927. It is a two-lane roadway, 3,345 feet portal to portal with a concrete finished interior. The ceiling height is 14 feet 10 inches. Average speeds are 30 mph during the day and 15 mph during peak traffic. It is lighted by two rows of 100-watt lamps in industrial type reflectors on 20-foot centers. Present average roadway illumination is about 1.5 footcandles. The walls and ceiling are now being steam cleaned.

Broadway Low Level Tunnel, Oakland. This ¾-mile, twin bore concrete finished tunnel was built in 1937. Each two lane roadway is lighted with one row of incandescent 100-watt lamps in glass refractors on 15-foot centers located on the ceiling 15 feet above the roadway. The present average roadway illumination is about 0.5 footcandle. The entrance treatment, designed by Mr. Romaine Myers, consisted of 190 feet of structural steel frame and egg-crate louvers over the roadway. It was carefully laid out so direct sunlight would not reach the roadway at any season of the year. This treatment was designed to help drivers adjust their eyes gradually to darker conditions as they entered the tunnel. It did a remarkable job for the existing speed of traffic at the time the tunnel was opened. The combination of exterior treatment and the very low level interior lighting is no longer adequate.

The San Francisco Broadway Tunnel, completed in March of 1953, is a twin-bore traffic arterial. It is 1616 feet long. Each bore providing two lanes of traffic is completely lined with two shades of pale yellow tile. The upper part of the tunnel down to the spring line has a reflection factor of 74.5 per cent. From the spring line down, the reflection factor is 65 per cent.

The lighting system consists of a single continuous row of plastic covered fluorescent units along the crown of each bore. Each bore is divided into three zones of lighting. Entrance lighting equipment, 560 feet long, has one row of T-12 430 ma lamps, and two rows of T-8 120 ma lamps. The middle section has one row of 200 ma and two rows of T-8 120 ma lamps. The roadway illumination furnished by this lighting equipment is as follows: entrance lighting, 26 footcandles, middle section, 22 footcandles; and exit section, 13 footcandles.

Waldo Tunnel: Recently, the California State

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 17-21, 1956, Boston, Mass. AUTHORS: J. R., Brass and Harold Skootsky, Engineers, California State Highway Department, San Francisco, Calif.; G. A. Trosper, Street Lighting Engineer, Pacific Gas & Electric Co., San Francisco, Calif.

Division of Highways completed a one-way high speed bore in Marin County for northbound traffic from the Golden Gate Bridge. It is 1000 feet long, 29 feet high, and 47 feet wide. Lighting in the completely tiled new tunnel consists of two lines of plastic covered fluorescent units, each containing two rows of 1000ma T-12 71-inch lamps and one row of 120ma T-8, 72-inch lamps. The T-8 lamps are for night lighting. One T-12 row in each line operates after the early morning daylight reaches three footcandles. The second row of T-12 lamps in each line operates after daylight illumination has reached 300 footcandles. The daytime illumination from artificial lighting in the center of the tunnel averages 60 footcandles on the roadway. The existing tunnel alongside has been reconditioned and relighted the same as the new tunnel.

Mr. Romaine Myers, who designed the structures at the portals of the Broadway Low Level Tunnel, said in his article in Illuminating Engineering Society *Transactions*, June 1939, " . . . where a speed of 45 to 50 miles an hour is maintained upon entering and passing through the tunnel, it is increasingly hazardous to the driver to become suddenly 'blind' for even a period of one second, as at a speed of 45 miles per hour the car travels 66 feet."

Mr. R. M. Swetland, in Illuminating Engineering Society *Transactions*, November 1941, made the following statement: "A car might be stalled some 50 to 75 feet inside the portal of such a tunnel and an approaching motorist, even at moderate speed, would have little opportunity of detecting the obstacle in time to prevent an accident."

These statements made at least 15 years ago picture conditions that are today basic problems of lighting tunnels.

By way of contrast: One of the oldest vehicular tunnels in this area was the Oakland-Orinda two-lane, unlined, timbered, horse and buggy tunnel built before the turn of the century. For a long time, 16-candlepower and 32 candlepower bare lamps were scattered along its 1100-foot length at about 50- or 60-foot intervals. One-half of this tunnel was in Contra Costa County and one-half in the City of Oakland. Contra Costa County ordered the local utility to modernize the lights in their half about 1925 by installing 100-watt lamps on 50-foot spacings in RLM industrial reflectors at the ceiling, about 15 feet above the roadway.

Perhaps we should try a different approach to the problem of tunnel lighting. There appear to be at least three questions that should be answered before a solution can be found.

First: What is the effect of the bright surroundings, illuminated with 6 to 10,000 footcandles of sunshine, on the driver's visibility as he approaches a tunnel entrance?

Second: At speeds of approximately 55 miles per hour, how long will the driver's eyes take to adapt from daylight conditions to tunnel interiors? Sufficiently for safe seeing? When we speak of 'drivers' eyes' we should consider the older eyes too. Drivers with eyes slow to adapt are driving the high speed, high powered cars of today.

Third: What is the optimum lighting for nighttime conditions?

Those of us who have been working at the State Division of Highways on tunnel lighting projects believe that much improvement in daytime entrance lighting is still required.

We also believe that many recent projects provide more light than necessary at night. Unfortunately these simple statements do not indicate simple problems.

We have found that it is not possible to justify tunnel lighting improvement on an accident or safety basis. Although it seems reasonable that poor visibility within a tunnel would lead to a great number of accidents, data from this area does not bear this out. Most drivers confronted with poor conditions for visibility will drive with caution and at reduced speed. Tunnel lighting design should therefore be based on providing adequate driver visibility and relieving driver apprehension, thereby allowing higher speeds with reasonable safety. Adequate tunnel lighting will most certainly reduce the possibility of one type of accident, *ie.*, collision with a vehicle stalled just within a dark entrance on a bright day.

Preliminary Ideas Based on Observations at Existing Tunnels Illumination Measurements Not of Great Value

The information we wish to present is unique, we believe, in that very little mention is to be made of horizontal footcandles; or for that matter, as in the paper "Lighting of the Brooklyn-Battery Tunnel" by Geenens and Reid (ILLUMINATING ENGINEERING, 1950, page 697) we also say very little about illumination on any plane.

Wall and Ceiling Brightness of First Importance

Also the roadway will be largely ignored as a factor in providing visibility within a tunnel. We consider wall and ceiling brightness from the drivers' point of view to be of greatest importance in tunnel lighting. This approach is simply the

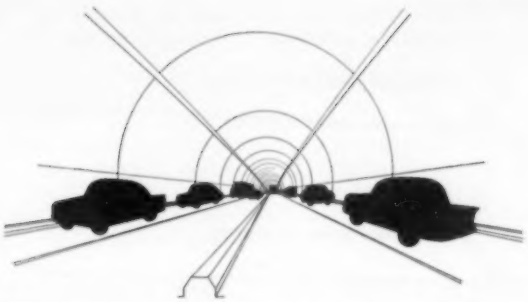


Figure 1. 90-degree perspective view, from South entrance of Park-Presidio Tunnel showing vehicles silhouetted against walls and ceiling.

result of observing how we best see on approaching and entering a tunnel. This is not to say that the roadway has no influence on visibility, but only that its role is much less important than commonly believed. See Fig. 1. In any case, if proper wall and ceiling brightness is maintained, adequate roadway illumination will automatically follow.

Continuous Lighting Most Effective Type

We are convinced that at the present time continuous line lighting is superior to other types of lighting for tunnels. The principal reasons for this belief are that the continuous line provides outstandingly uniform interior brightnesses, relatively low brightness sources, economical operation, and is generally considered to be aesthetically pleasing. See Fig. 4. We feel that these advantages offset the high initial cost. Conventional street lighting luminaires are entirely unsuitable for tunnel lighting, mainly because they concentrate light on the roadway and provide poor uniformity of wall brightness.

Three Problems of Daytime Lighting

Daytime lighting should provide for the following: First, satisfactory visibility into the tunnel for the approaching driver; second, adequate visibility instantly upon entering; and third, satisfactory visibility through the central portion of the tunnel. Figs. 2, 3, and 4 show approach conditions at the Park-Presidio Tunnel.

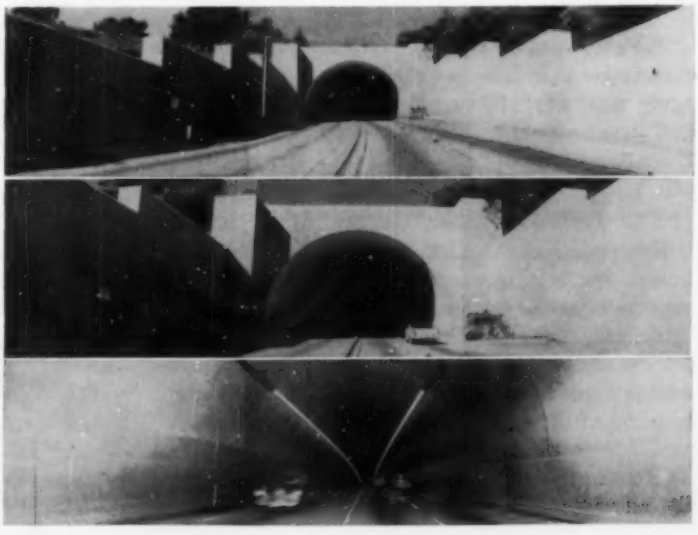
Long Adaptation Stages of Lighting Not Required During the Day

Some lighting engineers believe that daytime tunnel entrance lighting should provide for slow adaptation (10 to 20 seconds) to interior tunnel lighting after the driver has entered. We do not agree with this point of view. The Park-Presidio Tunnel in San Francisco proves to all observant drivers that a very short time is required to adapt to the 6-footlambert wall brightness. We have noted that the adaptation time varies among individuals, but no one has claimed that more than 2 seconds was required for satisfactory adaptation in this tunnel. The average driver passes completely through the 1300-foot long Park-Presidio Tunnel in 20 seconds. Recommendations based on 10- to 20-second adaptation time are apparently concerned with nearly complete adaptation which is not necessary. At the Posey Tube, which has an interior brightness in the range of 0.03 to 0.5 footlambert, satisfactory adaptation on a bright day occurs within three or four seconds after entering.

Figure 2. View 200 feet from South end of Park-Presidio Tunnel.

Figure 3. View 100 feet from South end of Park-Presidio Tunnel.

Figure 4. View at South end of Park-Presidio Tunnel.



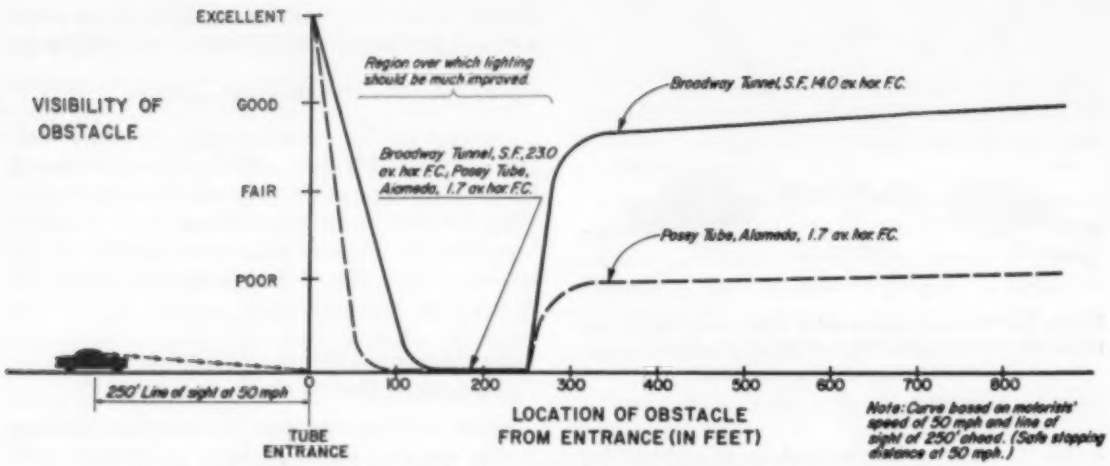

EXCELLENT
VISIBILITY OF OBSTACLE
GOOD
FAIR
POOR
Region over which lighting should be much improved
Broadway Tunnel, S.F., 14.0 ex hor F.C.
Broadway Tunnel, S.F., 23.0 ex hor F.C., Posey Tube, Alameda, 1.7 ex hor F.C.
Posey Tube, Alameda, 1.7 ex hor F.C.
250' Line of sight at 50 mph
0
100
200
300
400
500
600
700
800
TUBE ENTRANCE
LOCATION OF OBSTACLE FROM ENTRANCE (IN FEET)
Note: Curve based on motorists' speed of 50 mph and line of sight of 250' ahead. (Safe stopping distance at 50 mph.)

Figure 5. Visibility of obstacles (other vehicles) within typical tunnel and tube.

Improving Visibility for Approaching Driver

We are of the opinion that long stages of daytime adaptation lighting are wasteful in that light used in this way should be concentrated within 300 feet of the entrance to provide visibility into the tunnel for approaching drivers. Based on observation, we have developed a curve which shows relative driver visibility on approaching two typical tunnels on a bright day. See Fig. 5. It should be kept in mind that the driver is, at all times, looking at the roadway approximately 250 feet ahead which is a safe stopping distance at 50 mph. The curve indicates that the visibility of obstacles within the tunnel is poorest before entering and that improved lighting is needed for approximately a 200-foot section starting at the point where daylight penetration is not adequate. The lighting will also provide for adequate visibility instantly upon entering.

The above information is based entirely on field observations. It is hoped that those who may not agree with any of the preceding statements will find it convenient to make similar observations at the many tunnels in this area.

Some Characteristics of the Human Eye

Knowledge of certain characteristics of the human eye is of great importance in attempting to solve lighting problems. One of the most useful contributions to this knowledge came from the work done by Moon and Spencer concerning eye adaptation. Moon and Spencer established that the response of the small foveal area of the eye's retina accounts for approximately 90 per cent of the adaptation to a uniform field. It is also known that the fovea subtends only a one- to two-degree angle in the field of view. This basic information is of great value in explaining the effect of glare. For example, if a driver at night looks directly at approaching headlights, as we often do, the glare is blinding. However, if the driver looks only slightly away from these headlights, the glare is greatly reduced. Since the eyes are attracted to bright lights, it takes conscious effort to look slightly away from the headlights.

Daytime Lighting for Approaching Driver

During the day many tunnel entrances appear to be "dark holes" to approaching drivers. See Fig. 2.

In theory, using the relationship that the surrounding field will only have a 10 per cent effect on adaptation, it appears that a tunnel interior brightness equal to 10 per cent of the surrounding field would provide good visibility. As shown in Fig. 6 the average surrounding brightness at the

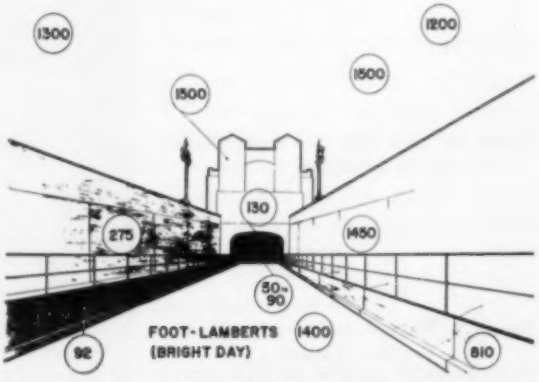


Figure 6. View 200 feet from Southwest entrance of Posey Tube, Alameda.

Experiments to Determine Satisfactory Entrance Interior Brightness of Posey Tube, Alameda, Calif.

Location: Posey Tube, Alameda, Southwest entrance.
Time: 3:00 p.m., July 19, 1955.
Weather: Clear, bright (slight haze).
Observation Position: 200 feet outside entrance of tube on East sidewalk (based on safe stopping distance at 35 mph).
Test Panel: 3½ feet x 3½ feet (Image larger than fovea at test distances).

TEST 1

The purpose of this test is to determine the panel brightness just discernible within the tube. When slowly approaching panel is seen, check shape of panel below. Immediately face away from tube, and *do not* discuss results with fellow observers.

(Reflectance of panel — 28.5 per cent.)

Brightness measured after all observers have faced away from tube, 7.0 to 8.5 footlamberts. (Use 7 footlamberts.)

TEST 2

The observer's judgment will be needed in determining the visibility of the panel at different brightnesses. (Indicate poor, fair, good, etc.)

Test No.		Observer No. 1	2	3	4	5
1	15 ft-L	F	F	F	F	G
2	60 ft-L	G	G	G	G	VG
3	60 ft-L	G	G	G	G	FG
4	30 ft-L	F	F	F	F	F
5	120 ft-L	E	E	E	E	E
6	30 ft-L	F	G	G	G	F

F — Fair; G — Good; VG — Very Good; E — Excellent.
Participants: Pacific Gas & Electric Co. — Messrs. G. A. Trosper, R. Benton. Westinghouse — Mr. J. Burson. Department of Highways — Messrs. Skootsky, Waight, Dienstag, Brass.
Meter: Spectra Brightness Spot Meter.

Alameda portal of the Posey Tube on a bright day was about 1000 footlamberts. It follows that about 100-footlambert wall and ceiling brightness within this tunnel would provide good visibility under these conditions. However, to determine if less brightness would provide satisfactory visibility a test was made. In this test the observers faced away from the entrance, except when signalled to make an observation. In this way the adaptation history of the observer's eyes was similar to that of the approaching driver. The test panel used was illuminated by daylight penetration. Different brightnesses were obtained by varying the distance of the panel from the entrance.

Those engineers who have been concerned with targets used in object visibility tests have questioned the validity of the target used. We wish to point out that this was not an object visibility test. Ideally the test panel should have been as large as the tunnel cross-section. The panel used was made as large as practicable.

Conclusions Concerning Daytime Entrance Zone Lighting

The following conclusions were reached as a result of studies, tests and measurements concerning daytime entrance zone lighting made at the Posey Tube:

(1) The average field brightness was about 1000 footlamberts.

(2) This very important effect was not anticipated: Haze composed of dust and vehicle exhaust, in direct sunlight outside the entrance, produced a veiling brightness superimposed on the entrance of between 50 and 90 footlamberts.

(3) The veiling brightness varied directly as the distance between observer and entrance, and with the concentration of haze.

(4) The unpredictable change in exhaust concentration apparently caused the variation between 50 and 90 footlamberts in veiling brightness.

(5) Surprisingly, the veiling brightness of 50 to 90 footlamberts was the greatest factor in hindering visibility of the tube interior from the 200-foot observation position. For this reason, as indicated by tests, wall and ceiling brightness of 30 to 60 footlamberts is required to produce a significant visible effect behind the veiling brightness. This is in agreement with the generally accepted statement that about a two to one difference in brightness is required to produce a significant visible effect.

(6) In order to determine the minimum maintained wall and ceiling brightness required to provide satisfactory daytime visibility for the approaching driver, consideration should be given to the worst conditions possible. This would include the existence of relatively poor eyes, dashboard reflections, dusty windshield, bright hood ornament, light colored hood, bright vehicles ahead, and a bright day with white clouds, considerable haze and veiling glare. Since the above mentioned conditions are beyond the engineer's control, it must be assumed that several of these effects could occur simultaneously, causing poor adaptation to tunnel interior lighting, even though great care has been taken to control surrounding brightnesses by painting and planting. For this reason we believe that painting of the portal surroundings is not of great importance.

(7) The maintained average wall and ceiling brightness in the entrance zone should be at least 30 footlamberts. Twice this level is recommended.

(8) Since it is impossible for all practical purposes, to maintain roadways as a good light reflecting surface, every effort should be made to produce the average brightness of approximately 30 footlamberts on the walls and ceiling of the tube. If this is done, the illumination on the roadway will be more than adequate regardless of the type of fixture.

Considering the above, and the fact that bright fixtures should be avoided because of glare, then it becomes apparent that direct lighting of the roadway would be undesirable.

In order to stress this point, make the extreme assumption that the roadway has zero reflectance. Direct light confined to this surface would be useful to light objects on the roadway. However, only light on the objects would be reflected, and the walls and ceiling would be dark. By directing the same amount of light only on 100 per cent reflectance walls and ceiling, the *same* amount of light would be directed on the roadway and visibility conditions would be greatly improved. Practical conditions are of course far less extreme, but the preferred method becomes obvious.

(9) The length of the entrance zone lighting should be about 300 feet to allow the approaching driver to see objects well within the tunnel. Three hundred feet is a safe stopping distance at 55 mph.

(10) Tiling of walls and ceiling in the 300-foot entrance section is economically advantageous for the above recommended brightness level, since at least five times the quantity of lighting fixtures would be required for equal wall brightness, with 10 per cent reflectance concrete. Measurements made at the Posey Tube give 12 per cent reflectance for the concrete walls. Ceiling darker.

Night and Day Lighting For Central Zone of Tunnel

As mentioned previously, the determination of illumination required within a long tunnel or tube becomes more a problem of providing adequate driver visibility and relieving driver apprehension than of increasing safety.

It is therefore necessary to rely on observations and judgment to determine proper night-time and daytime lighting in the central portion of a tunnel. The authors have made such observations and have arrived at the following conclusions:

(1) Visibility was judged very satisfactory when vehicles were clearly seen by silhouette against the tunnel walls and ceiling.

(2) The one-footlambert night-time wall brightness found at the Park-Presidio Tunnel provides outstanding visibility. As the result of tests, it is believed that this level could be reduced to one-third footlambert if uniformity is maintained, without sacrificing visibility. However, this lower level would be difficult to achieve even with only one continuous row of conventional fluorescent lamps, especially in a fully tiled tunnel.

(3) The initial 6-footlambert daytime wall brightness at the Park Presidio Tunnel appears to be just sufficient for central portion lighting.

The above recommendations indicate a ratio of daytime wall brightness to night-time wall brightness in the central portion of the tunnel, of about 20 to 1. As mentioned before, the low night level necessary to fulfill this requirement would be difficult to achieve with continuous fluorescent lighting and a fully tiled tunnel. A lamp with about 100 lumens per foot output would be required to produce the above mentioned conditions at Park-Presidio Tunnel.

The lowest output obtainable with conventional fluorescent lamps and auxiliary equipment is about 300 lumens per foot.

Additional light output, but not additional fixtures, is required in the central zone when the walls are not tiled. Therefore, tiling of walls and ceiling is not economically advantageous on a first cost basis, in the central zone. It is doubtful that the reduced energy costs with tiling will offset the first cost and tile maintenance.

Night Lighting for Entrance Zone

The entrance zone should provide the same lighting conditions at night as that recommended in the central zone. The entrance zone lighting at night should provide the recommended brightness, even if more light is used in the central zone.

Approach Lighting

Roadway lighting adjacent to tunnel portals should be provided. The amount and extent of this lighting will depend upon other exterior lighting and roadway conditions, each installation requiring special study.

We would like to stress that tunnel lighting research should include the making of careful observations. The above recommendations are based on the observations of a few individuals. In order to obtain more universally applicable data, more observations under widely varying conditions should be made.

Tunnel Lighting Problem and Solution

The following problem illustrates application of the ideas presented:

The problem is to light a vehicular tube:
Length of tube: 3500 feet.
Orientation: Southwest-northeast.

Cross section of traveled way: Rectangular.
Wall to wall: 30 feet (two lanes, two way).
Roadway to ceiling: 15 feet.
Wall finish: Concrete, unfinished.
Ceiling finish: Same as above.
Roadway: Concrete.
Traffic: Very heavy.
Street lighting in the vicinity: Low level.
Entrance surrounding brightness on bright day: 1,000 footlamberts (average).
Estimated maximum entrance veiling glare, due to sun on dust and heavy exhaust: 90 footlamberts

Recommendations for Entrance Zones

(1) Fully tile the entrance zones for a distance of 300 feet.

(2) Due to high veiling glare, provide two or more continuous rows of multi-lamp fluorescent fixtures in tiled entrance zones. These fixtures shall direct all light to the walls and ceiling, fixtures to provide a maintained 60 footlambert average wall and ceiling brightness of good uniformity. Fixtures to be mounted in upper corners so as not to restrict overhead clearance.

(3) Approximate total lamp lumens required per foot of tunnel length equals

$$F = \frac{B \times A}{MF \times FE \times R}$$

$$F = \frac{60 \times 60}{0.50 \times 0.50 \times 0.75} = 19{,}200 \text{ lumens/ft.}$$

B = Average maintained wall and ceiling brightness.
A = Area of wall and ceiling per foot of tunnel length.
MF = Maintenance factor (our experience indicates a factor of 0.5 is not too severe).
FE = Fixture efficiency (estimated as 50 per cent for multi-lamp fixture).
R = Reflectance of tile (approximately 75 per cent).

This equation is a rough guide, since light returned by the roadway is ignored and the factors included in the equation are estimated. However, measurements taken at existing tunnels indicate the error is not great.

Twenty rows of T-12 rapid-start lamps operated at 1000 milliamperes are required for this application or 10 rows of lamps on each side of the tunnel. Suitable fixtures must be of special design.

Recommendation for Central Zone

Beyond entrance zones provide two rows of fixtures to continue entrance lighting. Tiling not economically advantageous. Fixtures to provide a maintained average wall and ceiling brightness on concrete of 6 footlamberts (daytime) and 0.3 footlamberts (night-time).

Approximate total lamp lumens required per foot of tunnel length during day equals

$$F = \frac{B \times A}{MF \times FE \times R}$$

$$F = \frac{6 \times 60}{0.50 \times 0.70 \times 0.30} = 3430 \text{ lumens/ft.}$$

Four rows of T-12 rapid start lamps operated at 1000 milliamperes are required for this application (two lamps per fixture).

Approximate total lamp lumens required per foot of tunnel length at night equals

$$F = \frac{0.3 \times 60}{0.50 \times 0.70 \times 0.30} = 172 \text{ lumens/ft.}$$

Two discontinuous rows of T-8 slimline lamps operated at 120 milliamperes are required for this application. Lamps to be installed in every fourth fixture. This will provide a dashed line effect which should not be objectionable, especially with shielded lamp fixtures. If 100 lumen per foot lamps were available, the continuous line of lamps could be maintained.

This night lighting to be duplicated in the entrance zones.

DISCUSSION

R. M. SWEITLAND:* It appears appropriate, here, to inform all, who may *not* know, of the existence of an I.E.S. subcommittee on "Tunnel and Underpass Lighting" under our main committee on Street and Highway Lighting.

This subcommittee—of which Mr. Trosper is a member—has recently completed a report and recommendations on "Lighting Traffic Tunnels and Underpasses," for approval by Council. Consequently, this discussion by Mr. Trosper, and his associates, on "A New Approach to Tunnel Lighting," is most timely. However, some of the opinions expressed and data advanced in this paper appear to differ somewhat from the experience and recommendations of a majority of the subcommittee members.

For example, the committee majority advocates:

(1) A longer section of supplementary daytime entrance lighting, equivalent to 10 seconds driving time (minimum), for satisfactory eye adaptation and driver assurance and comfort. The West Coast paper suggests a 250-300 foot length, based quite largely on safeguarding entering traffic from possible accidents.

(2) A somewhat higher field-of-view brightness level inside the portal (under certain influencing conditions) to, again, aid driver adaptation under daylight conditions outside.

(3) A questioning of the existence of a pronounced daytime veiling haze, immediately outside the tunnel portal, to a degree which renders it a factor for universal considera-

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tion. However, should this portal haze exist, in some instances, the brightness levels inside the portal advised in the majority report are adequate to assure satisfactory entering visibility, and agree quite closely with those levels advocated by the authors.

And so, the resolving of these few divergent opinions and experiences, which are being given more consideration by the subcommittee, should strengthen the content of our resulting report and recommendations. Therefore we are indebted to these authors for their contribution to this end.

J. M. WALDRAM:* This paper on the lighting of vehicular tunnels is of special interest to me, as I have been working on tunnel lighting for some time, and am at the moment engaged on an investigation of a vehicular tunnel in England.

It is refreshing to find that we have been working on parallel lines. Some time ago it occurred to me that the methods recently adopted in this country for interior lighting, involving the use of curves of apparent brightness which allowed for adaptation, and of calculating interior lighting beginning with a specification of luminance, might be applied to the lighting of tunnels. Model experiments on the lighting of tunnel entrances were described in a paper to the Association Francaise des Eclairagistes at Monte Carlo in 1954, and were recently reprinted in England.[1] I have been able to apply these methods to a study of a tunnel here and have found them both helpful and realistic. We also use the method of perspective projection, which has been found so valuable in many problems of illuminating engineering.

In the lighting of the entrance, which is the main problem, we found, as the authors did, the following conclusions:

(1) The principal problem is not that of the rate of adaptation; this takes place very quickly, and little allowance for it is necessary. The trouble is that the adaptation level of an observer exterior to the tunnel is so high that the luminance of the tunnel walls and of objects silhouetted against them lies far below the instantaneous threshold of the eyes.

(2) This difficulty is further complicated by the effects of atmospheric scatter by the aerosols lying between the observer and the portal. We have measured a luminance of 38 footlamberts due to this cause, and verified it by calculation from Koschmieder's Law; it is evident that in certain circumstances, this luminance can rise to some hundreds of footlamberts constituting a veiling luminance which gives very little chance to any system of interior lighting of the tunnel.

(3) The vision of objects within the tunnel mouth by an observer outside can be secured by only two methods (a) by reducing the adaptation level of the observer, and (b) by increasing markedly the luminance of the background within the tunnel against which objects can be seen. Method (a) has been adopted, following the work of Romaine Myers, in the new vehicular tunnel at le Havre, France, where two funnel-shaped structures have been erected at the entrances and exits of the two bores, glazed with glass pavement lights. The second method has been tried in every modern tunnel, culminating in the great luminous ceiling at Croix Rousse, France, but it has not so far really succeeded.

(4) The reinforcement of the tunnel wall luminance must be carried on for a long distance if the tunnel is straight in plan, in order to provide a background to vehicles. The

Figure A. (Waldram discussion).

background must extend beyond the most distant vehicles which it is necessary to see; and from considerations of perspective foreshortening it must extend for some hundreds of feet. I also concluded that 300 feet is the least distance to which reinforcement should be provided; even then it cannot provide a sufficiently large background to cover vehicles in any position. If there is a curve in the plan, the problem is much simpler.

(5) Since the background is to be provided to reveal vehicles to an observer outside the tunnel, or just about to enter it, and since speed of adaptation is unimportant, there is no point in grading the luminance. It is needed at full luminance as far ahead as possible.

(6) There is no need for special treatment at the exit of the tunnel. Daylight is specularly reflected by the walls and deck to form an excellent background of high brightness and to provide adequate grading for re-adapting to the exterior luminances.

(7) Calculation shows that in the worst conditions which may occur, with a tunnel facing south, there is little hope of ever achieving sufficient luminance of the tunnel walls by conventional lighting systems of reasonable magnitude, and some other means must be sought for providing a bright background.

In my paper I made two suggestions. The first, which later was found to be not good, was to reduce the adaptation level of an outside observer by providing structures rather like photometric screens outside the tunnel, through which the driver would pass, and by keeping the portal reflection factor low. This fails because it does not much reduce the illumination of the intervening atmosphere, and the veil will remain. The second, which stemmed from an observation which I made at Boston when I was last in the United States, was to use louvers at the sides of the tunnel, which will appear to overlap when seen from the outside, and to make the louvers bright either by illuminating them, or by using a retro-reflecting material. (This latter idea was due to M. L. Gaymard of Paris, who tried it experimentally in an underpass there. It showed great promise and should be further investigated.) These louvers if 12 inches wide and spaced at 10 feet will provide a continuous background up to about 6½ degrees to each side. Thereafter the background becomes discontinuous and it can be arranged that the luminance of the panels diminishes. This should reduce the effect of flicker as the driver passes them. We hope to make further experiments with this system — some have al-

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ready been made — for it gives the best promise of providing sufficient background at reasonable cost and complexity.

1. Waldram, J. M.: "The Lighting of Tunnels," *Light and Lighting* (London), *49*, 51 (February 1956). Extracted from *Trans. Assoc. Francaise des Eclairagistes*, Monaco, 1954.
2. Huet, M.: "L'Eclairage des Tunnels Routiers du Havre," *Assoc. Francaise des Eclairagistes*, Tours, 1956.

ROMAINE W. MYERS:* In the discussion of this paper, I wish to present the economics of the use of "light transition louvers" at the entrance to tunnels, to reduce the natural outdoor brightness gradually before entering the tunnel, *vs* the build-up of brightness in the tunnel entrance, by artificial use of a large amount of fluorescent lighting with its resultant consumption of kilowatt hours of current.

The authors, under the paragraph "Broadway Low Level Tunnel, Oakland," refer to the entrance louvers over the roadway which I designed as follows: "This treatment was designed to help drivers adjust their eyes gradually to darker conditions as they entered the tunnel. It did a remarkable job for the existing speed of traffic at the time the tunnel was opened. The combination of exterior treatment and the very low level interior lighting is no longer adequate."

I wish to state that the louvers were designed for speeds of 45 miles per hour. The legal speed upon the opening of the tunnel, some 20 years ago, was 45 miles per hour; and 45 miles per hour is the present speed, with 36,000 automobiles passing through per day. Since opening the tunnel there have been over 150,000,000 which have entered and passed through. During this time there has been no physical accident on account of the inability to see upon entering the tunnels. The louvers are a success.

In discussing this paper further I wish to refer to a paper I presented[1] before the I.E.S. National Technical Conference in August 1939. Preface of the paper is as follows: "This paper describes a method of reducing the 'blind effect' upon entering tunnel and exit thereof, by the installation of overhead louvers, consisting of vertical and inclined metal strips, thus reducing the brightness ratio at entrance of tunnel. Safe driving visibility is assured by proportioning the roadway length of louvers as determined from tables of eye reaction based on travel at legal speed of 45 miles per hour."

To determine the limiting brightness values for ocular comfort upon entering tunnel at various speeds, it is necessary to study the time adaptation period of the eye in relation to brightness. Dr. P. G. Nutting upon the size of the pupil says:[2] "In normal eyes the pupil contracts automatically to protect the retina from excessive brightness and expands to admit more light to the retina when required. The diameter varies from about 2 to 8 mm on sudden exposure to a brighter light, the pupil contracts in about one second; on sudden lowering field brightness it expands to about 5 mm in about two seconds and then continues to expand slowly to the limit."

Tests on the average brightness of the field viewed and the corresponding diameter of pupil, together with the time in seconds of opening and closing of pupil have been made. The results are graphically shown in Fig. B.[3]

The authors have advised me that their estimated cost is as follows, for illumination of the entrances of the tunnels (two bores) to produce the existing brightness values as now obtained with the louvers is as follows:

Cost of fluorescent luminaires and their installation	$48,000
Annual energy charge	$ 3,240

The annual charge to amortize the above on the basis of a 30-year life with interest at 4 per cent amount as follows:

Amortization of $48,000 at 4%	$2,780 per year
Replacement of lamps (life 2 years) including labor	740 per year
Renewal of ballasts every 10 years including labor	340 per year
Energy (lighting current)	3,240 per year
Fluorescent lighting annual charges (approx. 15 ft-L brightness)	$7,100

I have carefully checked with the original sub-contractors, the replacement cost of the louvers at the present time including the supporting structure. This amounts to a total of $97,000. As the louvers are made of aluminum and have been installed for 20 years, it is safe to say that they are good for another 20 years. However, the same 30-year life will be used for amortization.

Amortization of $97,000 at 4%	$5,550 per year
Painting truss every 15 years	200 per year
Louver annual charges	$5,750

Summary

Fluorescent lighting annual charges	$7,100
Louver annual charges	5,750
Saving by use of louvers	$1,350
Saving by use of louvers for 30-year life	$40,500

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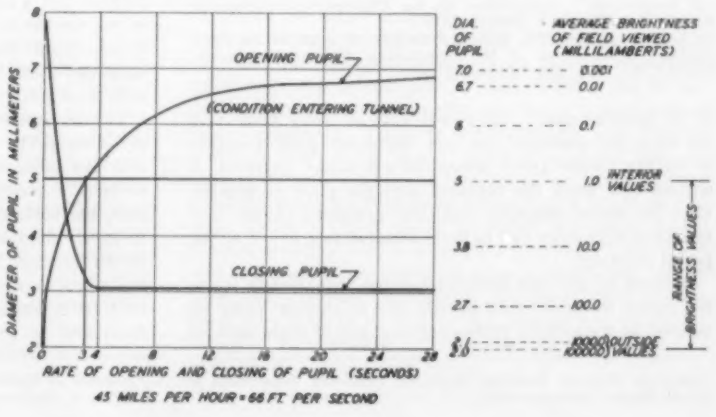

Figure B. Illumination studies for Broadway Tunnel. (Myers discussion).

Any advantage for speeds above 45 miles per hour that may be gained by the increase of the authors' recommended brightness values to 60 footlamberts, by fluorescent lighting, may in my opinion be offset at a much lower annual cost, by the extension of the louvers in the entrance zones an additional 100 feet, thus compensating for the time period for the pupil to expand on sudden lowering field brightness at increased speed. See Fig. B.

For speeds above 45 miles per hour the authors, under "Recommendation for Entrance Zones," recommend fixtures to provide a maintained 60-footlambert wall and ceiling brightness of good uniformity. To obtain this value they further recommend: "Twenty rows of T-12 rapid-start lamps operated at 1000 milliamperes are required for this application or 10 rows of lamps on each side of the tunnel."

To obtain the above values at the Broadway Low Level Tunnel (60 footlamberts brightness at entrance of two bores and 30 footlamberts at the tunnel exits), I estimate, with the reduced brightness at exits, the installation costs of the fixtures and their installation at $112,000. Yearly charges on an amortization basis of 30 years is as follows:

Amortization of $112,000 at 4%	$ 6,470 per year
Replacement of lamps (life 2 years) including labor	2,775 per year
Renewal of ballasts every 10 years, including labor	1,275 per year
Energy (lighting current)	8,900 per year
Fluorescent lighting annual charges	$19,420

The cost for louvers extended to a total of 300 feet would amount to the sum of $145,500. Yearly charges on an amortization basis of 30 years is as follows:

Amortization of $145,500 at 4%	$ 8,410 per year
Painting truss every 15 years	300 per year
Louver annual charges	$ 8,710

Summary

Fluorescent lighting annual charges	$19,420
Louver annual charges	8,710
Saving by use of louvers	$10,710
Saving by use of louvers for 30-year life	$321,300

The above comparisons substantiate the use of "light transition louvers," and show their economic importance in the design of tunnel approach lighting.

1. Myers, Romaine W.: "Light Transition Louvers for High Speed Vehicular Tunnels," *Transactions of the Illuminating Engineering Society*, Vol. XXXIV, No. 6, p. 621 (June 1939).
2. Nutting, P. G.: "The Retinal Sensibilities Related to Illuminating Engineering." *Transactions of the Illuminating Engineering Society*, Vol. XI, No. 1 (Jauary 1916).
3. Nutting, P. G.: "The Optical Principles of Illuminating Engineering." *Transactions of the Illuminating Engineering Society*, Vol. XV, No. 8, p. 529 (November 1920).

R. B. MARXHEIMER:* My recent visit of many tunnels in the East has convinced me how important good visibility is for the vehicle driver approaching a tunnel entrance. I noticed how much the reflected daylight glare is reduced when the portal retaining walls and pavement appear of a relatively dark color two to three hundred feet ahead of the portal entrance.

A blend of day and artificial lighting immediately inside the portal entrance could provide the brightness levels requested by the authors during daytime, and at night such an arrangement would be a good transition from the enclosed to the open roadway.

It seems to me and maybe to others that at 50 mph the vehicle driver looking directly ahead should be able to depend on a safe stopping sight distance in excess of 250 feet as mention in this paper.

It would be appreciated if the authors would elaborate upon and clarify the statement mentioning "the surrounding field will have a 10 per cent effect on adaptation, it appears that a tunnel interior brightness equal to 10 per cent of the surrounding field would provide good visibility."

This article gives an excellent description of tunnel lighting installations in the San Francisco Bay Area where the recent installations mentioned were designed for visual comfort.

It is hoped that the interesting investigations undertaken by the authors will be supplemented by brightness and visibility data on future tunnel lighting installations in California and other states, data which will show whether this approach to highway tunnel lighting proves to be valuable both to the vehicle driver and the illuminating engineer.

D. M. FINCH:* The authors' approach to the problem is fresh, new and stimulating. I am in accord with most of their basic premises. Certainly the existing technique of rating tunnels and other roadway facilities in terms of normal footcandles on the roadway is entirely inadequate. From personal experience I know that the five tunnels listed in the paper are not evaluated properly by indicating the average illumination on the roadway. Brightness data on the visual environment are absolutely essential to design a good job. The big problem is: What should these brightness values be? Whether or not the specific values of brightness in the approach, transition and central portions of a tunnel should be as recommended in this paper is a matter for further research but the principles presented seem to be sound.

These studies point up the fact that large capital and maintenance expenses are going to be incurred wherever adequate lighting is provided. The method of justification of such expense is not clear. This is a most important matter and should be developed. We know that the safety aspect of lighting is real, but reliance upon a reduction in the accident rate as a result of lighting is not too satisfactory. Many times there are other contributing factors which change when lighting is modified so that the exact contribution of lighting to the accident rate cannot be determined. Some much better tangible and measurable warrant is needed to justify the cost of roadway facility lighting. I suggest that a measure of the change in vehicular capacity of the roadway with and without adequate lighting should be attempted. Such a measure would have definite economic value and could be as useful in obtaining money for lighting as it is in justifying a grade separation at an intersection.

The assumptions used in the paper for adaptation time do not seem to be based upon adequate data. This coupled with the assumption of a 250-foot sight distance probably leads to a questionable length of transition section. However, the basic problem is properly stated and we do need to have a daytime as well as a night-time transition section in the lighting. I do not believe that the gradients in visibility are as shown. Visibility probably does not drop to zero for a normal target at 125 feet nor does it increase from zero to good between 250 and 300 feet within the

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Broadway tunnel. The slopes in the visibility curve should probably be less steep.

The selection of an entrance wall and ceiling brightness of 10 per cent of the surround is not on a firm basis. As a design ground rule this may work out all right, but more research is needed on this point. As a matter of practical engineering it would seem that until better warrants for lighting are developed it will be necessary to settle for less than 10 per cent wall and ceiling brightness for the entrance area under daytime conditions. Furthermore, the entrance area should probably have a rather steep brightness gradient within the first 500 feet.

The difference between daytime and night-time conditions should be clearly understood by the lamp manufacturers. It should be possible to obtain the 20:1 (or more) ratio desired.

The lighting requirements as determined by the calculations may be in serious error due to the reflectance terms that have been used. In determining the brightness of the walls or ceiling, one cannot use the ordinary diffuse reflectance. It is necessary to have the brightness factors for the materials for the particular angles of incidence and view. For tiled entrances, the brightness factor is probably greater than the 0.75 value of reflectance that was used. This would imply that substantially less than 19,200 lumens per foot would be required to obtain the 60-footlambert wall and ceiling brightness. As pointed out by the authors it is extremely important to have the answers to the design problems of lighting of tunnels as soon as possible. More research is urgently needed.

JOHN R. BRASS, HAROLD SKOOTSKY and G. A. TROSPER:* The authors wish to thank the discussors for the time and effort they put forth in commenting on this paper.

Mr. Swetland has indicated certain differences between the proposed I.E.S. recommendations on "Tunnel and Underpass Lighting," written by the subcommittee, and findings of the authors as presented in our paper. We believe the principal points of difference concern the reasons for and the extent of daytime entrance lighting. There is a persistent misunderstanding involved here. We do not propose 300 feet of high level daytime entrance lighting primarily for the desirable purpose of "safeguarding *entering* traffic from possible accidents," as Mr. Swetland stated. The entrance lighting we propose is to provide instantaneous visibility into the tunnel on a bright day, for the driver who is up to 200 feet *outside* the entrances. It will also eliminate the "black hole" effect. We have ample evidence, as reported in our paper, to prove that much lower light levels will provide for nearly instantaneous and satisfactory visibility upon entering a tunnel on the brightest day. The subcommittee recommendations are based on what we believe to be the erroneous idea that the driver must have 10 seconds or more time to adapt to high quality interior tunnel lighting after entering. The authors have reviewed and submitted comments on the proposed subcommittee recommendations on Tunnel and Underpass Lighting. The authors' paper was prepared after repeated efforts to obtain an explanation from the subcommittee as to why 10 seconds adaptation time is required to adapt to tunnel interiors, which are extraordinarily well lighted in comparison with previous standards. The only answer received refers apparently to tunnels with *inadequate* central zone lighting which, of course, could easily require 10 seconds adaptation time.

We do not argue that the eye adapts *completely* to the proposed interior lighting instantly upon entering, but we have incontrovertible evidence in the San Francisco Park-Presidio Tunnel that the central zone lighting we recommend provides very satisfactory and nearly instantaneous visibility after entering.

We are encouraged in our beliefs concerning entrance lighting by the supporting comments of J. M. Waldram and Romaine Myers, both of whom stated that an insignificant time is required to "adapt" to the relatively high levels of central zone lighting proposed by the authors.

The second comment listed by Mr. Swetland is not entirely clear, but we assume that the subcommittee advocates higher entrance lighting levels than do the authors for certain conditions. Since on a very hazy bright day average field-of-view brightness for an approaching driver may be as high as 2000 footlamberts, the entrance zone walls should be illuminated to provide no less than 1/15 of this value, or 133 footlamberts, to be in accordance with the I.E.S. subcommittee proposed recommendations. This level of brightness would be very difficult to achieve, but if necessary it should be accomplished. However, in this example, calculation of the required brightness is based on an arbitrary ratio of 15 to 1. We believe that only field tests can indicate the minimum satisfactory brightness level. The authors have, therefore, performed a test, as outlined in our paper, which resulted in the conclusion that bright haze over the entrance has a greater effect on obscuring vision into the tunnel than the surrounding brightness. Measurements made at five tunnels in the San Francisco Bay area indicated haze brightness of no less than 30 and up to 90 footlamberts (observer 200 feet from tunnel entrance looking into dark portal on bright day). J. M. Waldram of England has found haze brightnesses at an observer position of 300 feet of from 50 to 100 footlamberts (reported in correspondence to the authors). In the light of the above findings, we cannot agree with Mr. Swetland's statement that the haze described is not of universal importance. We believe that the taking of haze brightness measurements under standardized conditions at many more existing tunnels would be of great value.

Mr. Marxheimer has requested an additional explanation of our application of Moon and Spencer's findings concerning the well-known phenomenon that overly bright surroundings interfere with central vision.[1] Their findings indicate that if the brightness of the central portion (foveal image) of the field of view is not less than about 1/10 of the surrounding brightness (assumed uniform), visibility will not be disturbed by the surroundings. This is because the effect of the surroundings on adaptation is much less than the effect of the central zone which is imaged on the fovea (light sensitive cones are concentrated in the foveal area). It should be noted that this agrees quite well with the familiar 15 to 1 brightness rule for comfortable maximum contrast. The above-mentioned ratios provide comfortable vision and they do not indicate that visibility will be seriously impaired with greater ratios. This is a very common misunderstanding. Since we are concerned with visibility and not comfort in tunnel entrance zone lighting, the authors set out by a test, as reported in our paper, to determine the minimum brightness required on a bright day for good visibility. The results indicated that good, instantaneous visibility can be obtained at the Posey Tube with a wall brightness of 30 footlamberts on a very bright, slightly hazy day (average field-of-view brightness 1000 footlamberts, or a ratio of 33 to 1 for the existing haze condition). However, as mentioned in our paper and above, we do not advocate the use of simple ratios.

Mr. Marxheimer believes that we have not provided for

*Authors.

the required stopping distance at 50 mph in using 300 feet of entrance lighting. Information from the National Safety Council indicates that the emergency stopping distance, including reaction time, is 243 feet at 50 mph for a car with only passable brakes.

Mr. Marxheimer advocates darkening the outside portal area. We do not deny that such treatments are effective under certain conditions, but we have given several reasons why they are not a cure-all. Mainly, the outside portal treatment has no effect on veiling haze, brightness of vehicles ahead, bright hoods, bright dusty windshields or bright sky haze and clouds.

Mr. Marxheimer and Mr. Myers both favor entrance light control structures. We have not discussed such systems mainly because of the high initial cost, especially in the case where supporting side structures are required. In some situations, as at the Broadway Low Level Tunnel, retaining walls were required in advance of the portals and were also used to support the light control louvers designed by Mr. Myers.

There are certain disadvantages of louvers which should not be overlooked. Recent measurements made on a bright day at the Broadway Low Level Tunnel (approximate East-West orientation) indicated that since louvers let in light from the north sky, south walls are much brighter than north falls. In addition, the louvers let in only a narrow angle of light from the sky. This inherent defect of louvers accounts for the fact that even the south walls of unfinished concrete had an average brightness of only 15 footlamberts. This brightness could easily be increased to 30 or more footlamberts by painting or tiling. However, the north walls will still be about one-half as bright.

Mr. Myers claims there have been no accidents in the Broadway Low Level Tunnel due to poor visibility. Records indicate that there have been numerous accidents in the tunnel within the entrance zones during the day — many more than have occurred on the highway outside. The accident reports do not specifically mention poor lighting as a cause. However, maintenance personnel have noticed that drivers enter with caution, slow down and sometimes stop, due to uncertainty.

We are indebted to Mr. Myers for directing us to the work of Dr. P. G. Nutting, "The Optical Principles of Illuminating Engineering," (his reference 3), concerning the rate of change of pupil size for instantaneous changes in image brightness. This study is the only one of which we have knowledge which is directly applicable to the problem of daytime tunnel lighting. For example, the time given for the pupil to expand (2½ times increase in area) after changing from a scene of 1000 footlamberts to 30 footlamberts is only a fraction of a second. This does not mean that the scene of reduced brightness was not visible instantaneously, but only that it is seen *better* after the pupil adjustment.

If we devote little space to answering the comments of Mr. Waldram it is only because we are in such happy agreement. We have also used perspective drawings to determine the length of entrance zone lighting necessary. The only difference found here between Mr. Waldram's recommendations and ours is that he has concluded that *no less* than 300 feet of entrance lighting is required and we have concluded that *approximately* 300 feet is required (see curve). The exact determination of the length of entrance lighting is obviously somewhat arbitrary, although it should be no less than maximum emergency stopping distance. Of course, we also do not agree that artificial lighting of "reasonable magnitude" will not provide sufficient wall brightness at the entrance. We do recommend an unusually large amount of artificial lighting for tunnel entrance zones, but the quantity of light is, as shown in the example, within reason — less than half the brightness level required using the I.E.S. subcommittee recommendations for the same conditions.

Mr. Waldram's idea of using vertical strips of high

Time: 11:30 A.M. 11/28/56 Weather: Bright-Hazy
Location: Posey Tube, Alameda, Southwest Entrance

	$D_1 = 300$ feet		$D_1 = 200$ feet	
D_2	200 feet	100 feet	200 feet	100 feet
B_1	45	7.2	45	18
B_2	3.0	4.0	17 (Specular)	6.8
B_w	0.18	0.18	0.25	0.25

D_1 = distance in feet from tube portal to reflecting samples (within tunnel).

D_2 = distance in feet (parallel to tube axis) between reflecting samples and observer. Observer on opposite side of 50-foot roadway.

B_1 = brightness in footlamberts of Skotchlite No. 3270, wide angle, silver reflecting material.

B_2 = brightness in footlamberts of white reflecting material.

B_w = brightness in footlamberts of unfinished concrete wall.

Note: Reflecting samples were held at right angles to tunnel walls, although the brightness of "Skotchlite" sample was not critical with respect to angle with wall.

Meter: Spectra Brightness Spot Meter.

Approximate average brightness of entrance opening, seen from within tube, 5000 footlamberts.

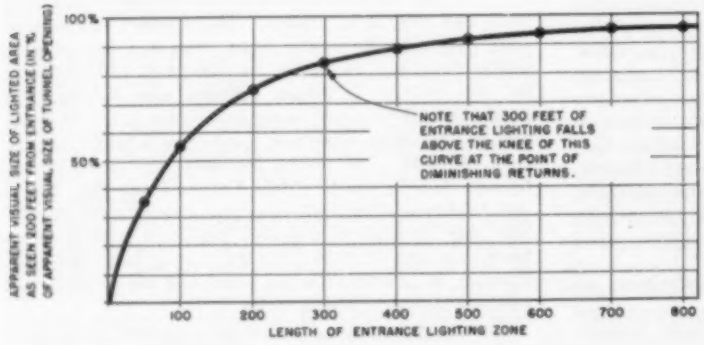
APPARENT VISUAL SIZE OF LIGHTED AREA AS SEEN 200 FEET FROM ENTRANCE (IN % OF APPARENT VISUAL SIZE OF TUNNEL OPENING)
100%
50%
NOTE THAT 300 FEET OF ENTRANCE LIGHTING FALLS ABOVE THE KNEE OF THIS CURVE AT THE POINT OF DIMINISHING RETURNS.
100
200
300
400
500
600
700
800
LENGTH OF ENTRANCE LIGHTING ZONE

Figure C. Curve showing apparent visual size of entrance lighting zone, based on rules of perspective drawing. (Brass-Skootsky-Trosper rebuttal).

reflectance on and at right angles to the tunnel walls within the entrance seems promising. The strips will reflect outside light producing the effect of bright walls. The addition of special reflecting material to the strips will enhance the effect. Relatively wide angle reflecting material is available which will appear bright from any location on the roadway. The table shows the results of tests made at the Posey Tube to determine the brightness of the reflecting strips at various distances within the tunnel entrance zone.

This test indicates that the reflecting louvers suggested by Mr. Waldram are extraordinarily effective in utilizing daylight from the portal. We have observed that the "Skotchlite" material can be clearly seen (observer 200 feet outside the tube) even when it is 400 feet or more within the tube (brightness of 30 or more footlamberts).

Many questions remain — can silhouetting alone provide adequate visibility of vehicles; if not, how much brightness from direct artificial lighting will be required in addition to the reflecting louvers; should walls and ceilings be lined with louvers; could louvers eliminate the need for night lighting; what are maintenance problems; and many others. This application of retro-reflecting material certainly merits consideration and experimentation.

It is encouraging to note the great interest in the very special problems of highway tunnel lighting. It has not always been recognized that vehicular tunnels should be lighted by methods very different from those used in highway lighting, but it is now apparent that much original work is being done the world over to improve lighting conditions in the often neglected tunnel.

1. Moon, Parry, and Spencer, D. E.: "The Specification of Foveal Adaptation," *Journal of the Optical Society of America*, August 1943.

The Evaluation of Discomfort Glare

(Addendum to paper by G. A. Fry, and discussion. Paper published in November 1956 ILLUMINATING ENGINEERING.)

G. A. Fry:* In the original draft of the paper, I inadvertently made the statement at one point that discomfort is proportional to area. What I should have said and did say elsewhere in the paper is that the capacity of a glare source to produce discomfort is proportional to its area.

There is no reason why we have to suppose that there is a linear relation between glare (the capacity to produce discomfort) and the amount of discomfort produced.

We have the same problem in connection with *luminance*** and *brightness*.** The basic current definition of luminance is capacity to produce brightness but this does not imply that there is a linear relationship between luminance and brightness. All that is implied is that two stimuli which have the same luminance have the same capacity for producing brightness. If two stimuli have different colors, we can assign to each of them luminance values and add the two luminance values and say that the two stimuli mixed together have the same capacity for producing brightness as a single stimulus of the same luminance. This is called the law of additive luminance and one can paint a perfectly satisfactory picture of the mechanism subserving this law.

In the same sense, we can say that each of two stimuli of different luminances or of different locations in the field of view has a capacity to produce discomfort which is proportional to its area. If we add their glare ratings, the combination of the two stimuli will have the same capacity for producing discomfort as a third stimulus having the same glare rating as the combination of the two. This is the law of additive glare ratings. As in the case of the law of additive luminance, one can paint a perfectly satisfactory picture of mechanisms subserving the law of additive glare ratings. This law can hold in spite of the fact that the relationship between discomfort and the capacity to produce discomfort is nonlinear and up to this point unknown. There will be second order exceptions to the law of additive glare ratings in the same way that there are second order exceptions to the law of additive luminance.

The glare rating system is more than a system of rating lighting installations in a certain order, although its use can be restricted to just this. The glare rating is an actual measure of the capacity to produce discomfort. We do not have to specify how much discomfort is produced except to say that the amount is the same as that produced by a given standard stimulus pattern.

This paper was written to show how a possible compromise might be effected in setting up a standard method of evaluating the capacity of a combination of glare sources to produce discomfort. The proponents of the different methods need to agree on a particular formulation of the relation between $\overline{Q}$ and B/P and S, and it is hoped that Mr. Logan and Mr. Lange will consider modifying their method of treating a combination of sources as suggested in the paper.

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**These terms are used here in the sense in which they are defined by the Optical Society of America.

DISCUSSION

Phelps Meaker:* My connection with Glare Factors has had to do mainly with the systematizing of calculations; trying to develop a routine such that it could be applied equitably by any who wished, with assurance that through standardization of the method there would be no unfairness.

*General Electric Co., Cleveland, Ohio.

I believe that in order to devise a workable method, a glare index proportional to area is absolutely vital. I do not think that we will have a convenient method or one which can be applied without unreasonable costs in time and money unless we can preserve those principles about which Dr. Fry has given us a great deal of encouragement. Standardization of application is particularly important, because even though the method may not be right — though it may be an approximation — if everybody follows the same procedure, I am quite sure that we will come out with satisfactory answers.

WARD HARRISON:* I did not expect to be called upon for discussion of this paper, but I am glad to say that in my opinion one need not be worried by certain discepancies which Dr. Fry has shown between the data by Luckiesh and Guth and what he terms the Harrison-Meaker method. The Harrison-Meaker proposals first emphasized that the effect of multiple glare sources was cumulative and the proposals were based on our experience extending over many years with practical lighting installations.

The first paper on glare ratings was presented a decade ago at the 1946 Conference. Our paper at that time was primarily a protest against the conventional method of deciding whether lighting installations were comfortable, which in general was to measure the brightest square inch and if it fell within certain limits, everything was all right and if it did not, things were all wrong. In those few instances where any relation between brightness and area did come in for consideration, it was usually stated that doubling the brightness of a light source was as serious as increasing its area sixteen times. Our paper was a protest against that also. Our experience indicated that doubling the brightness of a source was about equal to increasing its area four times. I have been interested to note that in the region where most incandescent and fluorescent lighting installations fall, the relation as shown by the Luckiesh-Guth data is very close to this latter figure.

We have always emphasized the need for more complete test data and information; Dr. Fry is to be congratulated on his paper.

SYLVESTER K. GUTH:** Dr. Fry has developed a most interesting analysis of the basic BCD data and of several methods for evaluating direct discomfort glare. His efforts are beginning to synthesize the several apparently widely divergent viewpoints and approaches to this problem. By bringing them together, as he has done in this paper, their similarities and differences become evident.

There are a few points in the paper which merit a comment or two. Equations (1) and (2) can be used for rating sources and G and M are related as shown in Fig. 3. However, Equation (1) is based upon determining Q from Fig. 9 and Equation (2) refers to Fig. 6. As Dr. Fry points out, the curves of Figs. 6 and 9 are tangent in the region where Q is 0.02 steradian. It is obvious that the curves diverge for larger and smaller values of Q. Thus, apparently inconsistent ratings could be obtained from the equations for G and M. Fortunately, the range of Q for which the coefficient of 55.6 in Equation (1) is applicable seems to provide fairly good agreement with the experimental data for most typical lighting systems. It is only when the total Q of the lighting system is very small or very large that differences may warrant using other values for the coefficient. Dr. Fry's recognition of this is indicated by his statement that if the relationship between G and VCI is constant, the relationship between M and VCI need not be constant. It is also possible for M vs. BCI to be constant and G vs. VCI to vary. In other words, the relationship between G and M would not be constant for all values of Q but would consist of a family of curves.

In spite of one or two statements in the paper, I am sure that Dr. Fry does not intend to imply that discomfort is proporional to area. That is, doubling area does not necessarily double the sensation of discomfort. However, according to Equation (12) the glare rating G — or capacity to produce discomfort — is proportional to area. The nonlinear relationship between G and discomfort (VCI) is illustrated by Fig. 4.

Dr. Fry's proposed principle of additivity, while not strictly true, will be workable. The recent researches on discomfort glare indicate that the summation is a complicated function of a number of factors. Nevertheless, if it is remembered that Dr. Fry is adding ratios which represent relative discomfort ratings, the sum will be an evaluation of relative discomfort. By means of appropriate data these ratings can be related to some sort of sensory scale such as a visual comfort index or to the degree of discomfort experienced by an individual.

This paper is a real step forward toward the development of an I.E.S. method for evaluating discomfort glare. If Dr. Fry's proposals are accepted by the S.Q.Q. Committee — as we have every indication to believe — it may be that the long-awaited report on this subject will soon be forthcoming.

H. L. LOGAN:* I congratulate Dr. Fry on this able mathematical analysis of the several proposals now current for the evaluation of direct glare. As far as I understand his suggested modification of the Logan-Lange method, it consists of assuming a family of G curves that are the same shape as the related F curves with which each is associated, and transposing $\overline{B}$ values laterally to the related G curve, instead of transposing them along the F curve on which the original values lie. This results in a set of numerical values, which, when translated into comfort response percentages would apparently lie between those than follow from the Harrison-Meaker method and the Logan-Lange procedure.

There is a great deal of "haze" in this subject, beginning with matters concerning the procedure, and the observers in the original experiments; the assumptions made in interpreting the results; and then the haze in the numerical quantities that must be fed into any application method, caused by the mechanical difficulty of correctly determining these quantities. There are other factors of uncertainty, so that it has long been evident that a practical method of direct glare assessment would have to be a compromise based on our best knowledge and judgment.

The justification for a compromise is that even our present methods give remarkably consistent results that are usually in line with the quality of judgment made by lay observers, but because they do not give exactly the same results some confusion is caused in some quarters. Therefore, a compromise between them is in order, and it looks as if Dr. Fry has come up with an acceptable compromise that will work within the limits of the size of sources used in the Luckiesh-Guth experiments.

It cannot be used for large area sources because if the formula used by Dr. Fry to express the form of the Guth

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curves is extrapolated into the region of large area sources (above 0.1 steradian, or 2 per cent of the visual field) it leads to the untenable conclusion that a light source that occupies about 10 per cent of the field of view becomes uncomfortable just by virtue of size. All natural scenes would, therefore, be uncomfortable, as Dr. Spencer has pointed out. For large area sources the Logan-Lange method still offers the only available way to estimate the visual comfort effect. It will be interesting to see how much visual comfort predictions for large area sources, by the Logan-Lange method, will be affected by applying Dr. Fry's phantom G curves to that portion of the Logan-Lange curves beyond $Q = 2$ per cent of the visual field.

In conclusion, I believe that Dr. Fry's compromise method will apply to a large percentage of modern indoor lighting practice; certainly to the vast host of lighting "fixtures" as distinguished from large panel and luminous ceiling lighting; and within this range will remove such confusions as now exist, by giving us one set of comparable values for each situation.

Lighting Requirements for Older Workers

(Discussion on paper by S. K. Guth, A. A. Eastman and J. F. McNelis, published in October 1956 ILLUMINATING ENGINEERING.)

RAY P. TEELE:* In our work on the visibility function at the Bureau we used over 100 observers divided roughly in the same age groups. Here, we were using flicker technique and wavelengths in the blue and were not concerned with recognition of a word but the effect of age was very definite. Our method would not separate a sensitivity change in the retina from a loss of transmission of the eye media. These would be lumped together as one thing in this technique and the loss in the response, let us call it, progressed definitely with age as a straight line. It showed a yellowing of the eye media. I just wanted to point out that part of the process, at least, loss of transmission of the eye media and the response would be involved in your results, and from our work that is a straight line with age. The youngest we had was about 19 but there was no evidence of a plateau of any kind. Apparently our eyes start to age as soon as we start to use them.

JOHN A. HANSON:** This paper serves a useful function in demonstrating that for a particular criterion of visibility, lighting requirements do vary over a considerable range as a function of the age of the observer. As the authors point out, however, the large variability of lighting requirements for individuals within a relatively homogeneous age range is so large that it makes any predictions based on mean performance of an age group rather hazardous.

A question I would raise in regard to the technique used in this study to determine the lighting requirements is, is it legitimate to use the amount of degradation a visual task can tolerate as a criterion of visibility? This, in effect, is what the Luckiesh-Moss Visibility Meter is doing by varying the brightness-contrast characteristics of the viewing task. Certainly it is possible to define visibility in this manner. However, if the aim of the study is to provide information as to lighting requirements for efficient performance on some visual task, it would seem that a performance criterion would be more meaningful. To generalize that the visibility, as measured with the L-M visibility meter, is related to performance, one would have to assume that performance varies with illumination in much the same manner that recognition thresholds vary with brightness-contrast and diffusion over the same range of illumination. It would seem to me that such an assumption cannot be made for most visual tasks.

Getting back to the data presented on lighting requirements for the various age groups to achieve a particular visibility criterion, it is interesting to note that the magnitude of the differences in illumination required by the various age groups is about in the range of what would be predicted on the basis of the data presented by Birren and others on age changes in pupil size.

G. A. FRY:* The authors have demonstrated in a most satisfactory way that even when people are fully corrected with lenses they have different lighting requirements.

It would be interesting to study the role played by variation in pupil size. This could be done by measuring pupil size or by using an artificial pupil. It is to be noted in Table IV that the total range of variation required for a given level of visibility is from 15 to 105 and except for two cases the range is from 15 to 75. The diameter of the natural pupil can vary from 1.6 to 8 mm. It is quite likely that pupil size is the major cause of the variations in visibility.

We need more data on variations in pupil size with age, and variations in pupil size from individual to individual at the various age levels.

It would also be of interest to obtain such data on the separate eyes. Impaired vision of one eye is not detected when both eyes are tested at the same time. Hence when the measurements are done binocularly, one is apt to miss the opportunity of studying the effect of impairments which are not corrected by glasses.

EDYTHE POLSTER:** I believe another matter to be considered is the specific physical condition of each subject. I think this is very important because the aging process is a highly variable one and by the same token the diminishing

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of visual acuity is highly variable. I have, for instance, no business having 20/20 vision at my age, but it is very convenient. And, of course, I want to stress the agreement with Dr. Hanson about the importance of knowing the variables connected with performance of task because I think it is very important that we do not judge simply on reading acuity in these tests.

DOMINA EBERLE SPENCER:* I would first like to congratulate the authors on their paper which seems to me to be valuable and useful. Then I would like to ask a few questions. In the first place, does this work mean that whenever anyone is making a recommendation of quantity of light to be used in a specific application it should be made in terms of both the task and the age distribution of the occupants? For example, in the case of a classroom, both very young students and somewhat older teachers should be considered. Could this be construed to make us feel that there were definite advantages in going quite far above the 30 lumens per square foot recommendations for classrooms which is so often quoted, frequently to the annoyance of the lighting engineer? It seems to me that investigations of this type would indicate that the choice of a comparatively low quantity of light which is supposed to be adequate for the average observer is unsatisfactory for many individuals and that the benefit of larger quantities of light to an appreciable fraction of the people in any luminous environment should be emphasized very strongly whenever we are making recommendations on the quantity of light.

Now the second question is this. The authors have said that assuming as they do with the visibility meter that the surround is essentially uniform, the requirements for quantity of light increase with age. Is there any available information on the related question as to whether the effect of non-uniformity in the luminous environment may also change markedly with age? For example, would it be desirable to consider repeating tests such as those made by Holladay and Stiles-Crawford, on which Professor Moon and I have based our analysis of the non-uniform surround, with a variety of observers? The effect of non-uniformities in the field of view for observers of various ages and for observers with less than 20/20 vision might be even more important than for young observers with "normal" vision. In connection with this question, I would particularly like to ask Guth whether there has been or should be any investigation to determine whether his BCD method of analyzing discomfort may be a function of age of observer. It seems to me that if we could say that older people or people with imperfect vision needed to have a very high quality luminous environment this would be of considerable significance in lighting design.

S. K. GUTH, A. A. EASTMAN, J. F. MCNELIS:** There are a number of probable causes for the lower visibility levels obtained by various observers, especially those in the older age groups. The yellowing of the eye media, mentioned by Mr. Teele, will have an adverse effect upon the brightness of the retinal image. Similarly, as noted by Dr. Fry and Dr. Hanson, the retinal brightness will be less for those observers who have smaller pupils. Such reductions in retinal brightness are equivalent to a reduced illumination of the task for these specific observers. The considerable variations among observers, even for those within a given age group, would seem to indicate that the differences in visibility are caused by various physiological factors as well as these two more-or-less optical factors.

A knowledge of all the causes of subjective differences is important for a better understanding of *how* and *why* people see as they do. However, our primary purpose was to determine *what* effect, if any, the age of an observer might have upon visibility. A study of the contributing physiological factors was outside the scope of this investigation but we intend to include them in future experiments.

Dr. Hanson questions the legitimacy of using the amount of degradation a visual task can tolerate as a criterion of visibility. Basically, visibility or the degree a task is suprathreshold usually is evaluated in terms of how much its size, brightness, contrast or the time available for seeing must be reduced for the task to be at the visual threshold. The Luckiesh-Moss Visibility Meter is a portable instrument for accomplishing this in terms of a combination of brightness and contrast. It has been found useful for evaluating the visibility of practical tasks in typical work-world situations and for determining the footcandle levels required for these tasks to be of equal visibility.

Dr. Hanson's real questions pertain to the relationship between visibility and performance. Visibility is a "static" measure of visual ability, whereas performance generally is evaluated "dynamically" in terms of speed and accuracy of working. Obviously, a visibility meter does not assess performance directly. However, it certainly is necessary to have some degree of suprathreshold visibility in order to achieve efficient performance. Furthermore, efficient performance requires good visual ability. The latter is indicated by the visibility level achieved. In other words, there is a relationship between visibility and performance, but not necessarily a linear one.

We agree with Miss Polster that many factors must be considered in the overall evaluation of performance. The visibility technique is particularly useful because it appears to provide an integrated evaluation of ability to see by taking into consideration the difficulty of the task, the visual status of the individual, certain physiological factors, etc.

In answer to Dr. Spencer's first question, most certainly lighting recommendations should be in terms of the task and of the individuals who must perform the task. Since lighting is being provided so people can see, it is important to consider their overall visual abilities. Age is only one personnel factor. The individual differences among those in a given age group would seem to be of even greater importance. The economic compromises which generally influence recommended levels of illumination should not be permitted to outweigh the benefits received from improved lighting and more adequate footcandle levels.

An examination of our BCD data does not reveal that brightnesses judged to be at the border line between comfort and discomfort are a function of the ages of the observers. None of the older observers seemed to be any more or any less sensitive to brightness than were the younger observers. This appears to be contrary to often-made statements that older persons generally are more sensitive to brightness. It seems to us that every field of visual and lighting research should include investigations with large groups of observers of all ages. As we have pointed out previously, too much is based upon averages which can lead to narrow and unjustified conclusions.

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INSTALLATION AT LEON'S JEWELRY STORE, 258 LINCOLN HIGHWAY, COATESVILLE, PA.

Lighting a Jewelry Store

LIGHTING OBJECTIVE: To provide an inviting atmosphere for prospective customers and to enhance the jewelry, china and glassware, etc., displayed.

GENERAL INFORMATION: The floor area in this store measures 15 by 93 feet. Ceiling height is 12 feet. Sidewalls are green pegboard (65% RF) and the floor is black (22% RF) and yellow (34% RF) tile.

INSTALLATION: The front (jewelry) section is lighted by a combination luminous (Benjamin Panel-Glo) and plastic louvered (Benjamin Sky-Glo) ceiling. The plenum above is 18 inches deep and finished with 80 per cent reflectance white paint. Above the shielding are five rows of three 96-inch T-12 (75-watt) slimline fluorescent lamps. In addition, centered over the louvers there are 14 150-watt R40 reflector spotlamps. The floor cases have four 40-watt and two 30-watt fluorescent lamps in reflectors, and the wall cases eight 40-watt fluorescent units.

The center 50-foot section where china and cards are sold is lighted by four nine-foot long custom-built units as shown in Fig. 2 (each contains four 96-inch T12 lamps) and 20 150-watt R40 reflector spot units (Swivelier B-81) between the fixtures. In addition, there are nine 30-watt T8 lamps over the card displays. All fluorescent lamps used in this installation are standard cool white color.

The 8 by 18-foot china and glassware section at the rear of the store (Fig. 3) is lighted by six

(over)

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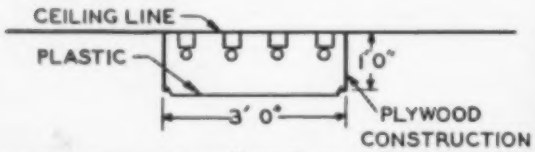

Figure 2. (above) Cross-section of custom-built unit.

Figure 3. (right) China and glassware section at rear of store.

150-watt R40 reflector spot units (Swivelier B-81) and a decorative crystal chandelier. The showcase has six 75-watt R-30 reflector spots on top and two 30-watt T8 fluorescent lamps at the bottom.

Resulting average illumination and brightness readings with all lighting operating are as follows:

Front Section (Jewelry)

Horizontal illumination	95 ft-c
Floor showcases	190 ft-c
Wall showcases	100 ft-c
Luminous ceiling	
at 45 degrees	95 ft-L
at 0 degrees	115 ft-L
Louvered ceiling	
at 45 degrees	55 ft-L
at 0 degrees	190 ft-L
Wall	31 ft-L
Floor	8-12 ft-L

Center Section (China and Cards)

Horizontal illumination	50 ft-c
Vertical illumination	40 ft-c
On cards	95 ft-c
On china	80 ft-c
Custom-built fixture	
45 degrees crosswise	340 ft-L

Rear Section (China and Glassware)

Horizontal illumination	25 ft-c
Vertical illumination	150 ft-c
Rear shelf	160 ft-c
Side counter	100 ft-c

Lighting designed by Michael N. Flynn, Benjamin Electric Manufacturing Co., Philadelphia, and S. W. Purdum, Philadelphia Electric Co.

Lighting data submitted by Messrs. Flynn, Purdum and George T. Anderson, Jr. (Philadelphia Electric Co.) as an illustration of good lighting practice and to aid in the design of similar installations.

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A Highway Lighting Test Installation

By GEORGE A. NAGEL

This paper presents information and public opinion data pertinent to the problem of lighting turnpikes so as to be pleasant and attractive as well as safe for night use.

THE STATE OF Connecticut is presently engaged in the construction of the Connecticut Turnpike, a new expressway which will extend approximately 129 miles from the New York State Line at Greenwich, Connecticut, to the Rhode Island State Line at Killingly, Connecticut. One of the many problems in the design of this expressway is highway lighting. There are approximately 50 interchanges in the 53 miles of expressway comprising the western portion of the turnpike, and this portion will be lighted in order to accomplish three main objectives:

a. To reduce night-time accidents by providing brightness contrast to permit obstacle recognition.
b. To contribute to driver comfort and thus tend to lessen the early evening peak loads by stimulating night-time driving.
c. To increase roadway capacity through traffic placement more nearly in accord with the daytime pattern.

Our State Highway Commissioner, Mr. Newman E. Argraves, is fully aware of the problems that the Connecticut Turnpike presents, particularly in view of the fact that the opening of the expressway will be about December, 1957. His approval of a test lighting installation probably represents the first time that a State or municipality has made such a large scale, comprehensive evaluation of the different types of lighting under actual highway conditions. Naturally, the State of Connecticut is anxious to provide a lighting installation that will offer the most for the investment made, and one that is sufficiently modern so that it will not be obsolete within a few years after the opening of the turnpike.

Problem

This new turnpike will provide night access between a series of sizeable population centers, and night traffic volumes should be of a high order. We feel that there is a fork in the road where street lighting and highway lighting diverge, yet the information most readily available in connection with roadway illumination is that which applies to street lighting as distinguished from highway lighting. Under expressway driving conditions, the driver's normal field of view consists of the roadway and adjacent areas, vehicles and luminaires; and the luminaire brightness will usually be contrasted with the darkness of the night rather than the higher brightness which foliage, building facades, etc., often provide for luminaires when installed for street lighting. Under expressway driving conditions, there should also be a minimum of pronounced flicker effect from the luminaires even when vehicles are traveling at the highest speeds to be permitted on the expressway.

The problem of the State, therefore, resolves itself into a selection of a type of roadway lighting which will result in improved night-time driving conditions and furnish adequate, comfortable lighting, sufficiently modern to be in accord with present design trends.

In modern roadway lighting, neither the intensity of the illumination on the roadway surface, the light source selected, nor the light produced tells the whole story. The effectiveness of highway lighting is a function of the driver's vision, his reaction, the brightness and contrasts produced by the luminaires, and their lighting of various surfaces and objects encountered.

We all know that the relative effectiveness of different types of highway lighting should be subject to measurement, but this, however, involves the human psychology of those who will pay to use the highway at night. In view of this, it is possible that, at present, highway lighting could well be measured by competent, comparative observations of its relative effectiveness. Obviously, the observations and preferences of the people are important, and doubtlessly, the public opinion which we have obtained will be correlated with data on seeing comfort and visibility. We believe this to be particularly true in the case of linear lighting sources where it has not been definitely established, to

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 17-21, 1956, Boston, Mass. AUTHOR: Associate Highway Engineer, Connecticut State Highway Department.

the complete satisfaction of all concerned, that presently accepted photometric design values are applicable.

In view of the above, the design engineer faces a difficult problem in his endeavor to evaluate various light sources and provide an acceptable highway lighting layout.

To help resolve some of the problems involved, it is indicated that a need exists for determining:

1. Driver preference for any particular type of lighting.
2. Driver reaction under the various types of highway lighting.
3. Whether or not lower levels of illumination can be tolerated with some types of luminaires and still have adequate visibility.
4. Whether any type of lighting shows an advantage in illuminating different types of pavement surface.
5. Whether any of the light sources reflect an advantage when driving under wet pavement, dry pavement, or foggy conditions.
6. Whether any of the types of lighting reflects an advantage under sustained high-speed driving and high contrast conditions existing on highways.

Obviously, to arrive at solutions for the above problems, it will be necessary to have basic formulas in connection with, for example, disability veiling brightness and discomfort glare. It will also be required that the accepted borderline between comfort and discomfort under highway driving conditions be established so that the lighting engineer will have proper information on which to base his design.

Test Installation

In order to assist in evaluating the various types of lighting for application on the Connecticut Turnpike, a test installation was decided upon by the State of Connecticut so that a comparison could be made under actual highway driving conditions. The section of roadway selected for the test is part of the present Route U. S. 1 and is just east of, and adjacent to, the Raymond E. Baldwin Bridge over the Connecticut River. It will become part of the route of the Connecticut Turnpike. The test strip is approximately one mile in length and is located in the Town of Old Lyme, Connecticut. It is a four-lane divided highway with a width of 55 feet between outer edges of pavement.

There were mounted on the test strip 27 fluorescent and 22 mercury vapor luminaires, which number was chosen in order to provide both black top and concrete pavement under each type of lighting. The luminaires are spaced 100 feet staggered (200 feet between poles on each side of the roadway) and mounted over the edge of the pavement at a height of 30 feet. The luminaires are rated 21,000 lumen (approximately) for both the mercury vapor and fluorescent lighting with the latter mounted at a 25-degree tilt.

As a result of the test lighting installation, there were made available to the State of Connecticut 10 linear low-brightness luminaires using a mercury lamp. These were installed at the east end of the test strip after the public opinion sampling had been taken, but prior to the time that instrumentation was undertaken and, also, prior to the taking of the test sequence photographs. The present installation, therefore, consists of 10 linear mercury,* 12 conventional mercury, and 27 fluorescent luminaires. The test results hereinafter given for the public opinion sampling do not include the linear mercury luminaires.

The conventional mercury luminaires have glass refractors; the fluorescent luminaires have a clear Plexiglas globe; and the linear mercury units are of the open bottom type.

Figs. 1, 2, and 3 show the various installations. Fig. 4 shows typical pole spacing and test stations.

Since the Connecticut Turnpike will be an eight-lane divided highway in certain sections, it was deemed advisable to be able to light one side of the test strip independently of the other in order that lighting of such a wide section of roadway could be evaluated. Switches are provided so that the luminaires along either side of the roadway can be lighted.

Evaluation

Observer and Driver Reaction

We believe that one of the outstanding accomplishments of the test installation has been the public opinion survey conducted at this location.

In order to evaluate the lighting, there were invited several groups to inspect the test lighting installation, and these groups were asked to fill out comment forms. Table I shows the questionnaire submitted to the invited groups, and the totals in the various columns represent the summation of their replies.

Group I was a controlled group of 31 men well-acquainted with street and highway lighting problems and techniques. They were briefed as to the object of the inspection trip and as to what should be given special attention by the viewers. After darkness, the group was transported in passenger cars through the test area (eastward) to a point approximately one-half mile beyond the test in-

*The coined term "linear mercury" luminaire will be used throughout the paper to designate a linear low brightness luminaire, i.e., a luminaire with an elongated reflector distributing light from a 400-watt EH-1 type lamp with resulting low brightness somewhat similar to that of the fluorescent luminaire using a linear light source.

Figure 1. Fluorescent luminaires installed on test lighting strip, Old Lyme, Conn. Official photograph, Connecticut State Highway Department.

Figure 2. Conventional mercury luminaires installed on the test strip at Old Lyme, Conn. Official photograph, Connecticut State Highway Department.

Figure 3. Linear mercury luminaires installed on the test lighting strip at Old Lyme, Conn. Official photograph, Connecticut State Highway Department.

stallation in order to permit dark adaptation prior to the return trip. In the easterly direction the observers first passed through existing incandescent lighting on the Raymond E. Baldwin Bridge, then through the fluorescent and the conventional mercury section. The lighting on the return trip was in the reverse order. The speed of travel varied between 20 and 50 miles per hour during the test run with most of the speeds being at 35 miles per hour.

The viewers were then asked to observe the area as pedestrians, and the lights on the north side of the test area were extinguished so that the observers might see how far the illumination would extend. At the time of the inspection, the pavement was damp since there had been rain in the early afternoon. Rain stopped at 7:00 p.m., and pavement had no standing water.

Group II was a controlled group of 29 men,

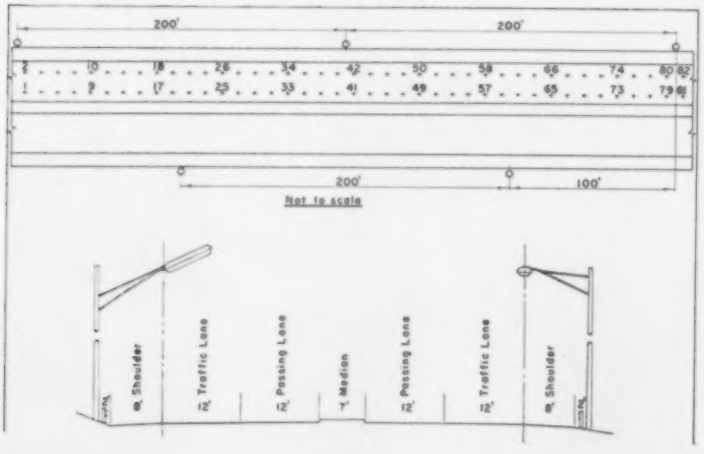


Figure 4. Plan showing test station locations and section of typical test strip roadway.

TABLE I — Lighting Evaluation.
Summation of Results of Groups I through III inclusive.
Test Installation, U. S. Route 1, Old Lyme, Connecticut.

	(X) Linear Mercury	Mercury	Fluorescent	No Preference
1. Less objectionable glare from lights				
a. when driving	2	40	23	8
b. when standing	3	31	31	7
2. Asphaltic pavement appears brighter under	3	52	8	8
3. Concrete pavement appears brighter under	2	52	12	7
4. More uniform pavement brightness				
a. when driving	3	42	19	8
b. when standing	3	39	18	12
5. Better over-all color appearance under	2	15	37	19
6. Better object silhouetting				
a. asphaltic pavement	2	43	8	20
b. concrete pavement	0	41	13	19
*7. Less glare from approaching headlights	0	12	7	23
8. Objects on road shoulder seem better under	0	40	22	11
9. Generally, I feel more comfortable driving under	1	50	22	4
10. In sustained driving (*e.g.*, 1 hr. at 50 MPH) I believe that loss monotony and fatigue might be experienced under	0	44	15	14
11. I prefer the daytime appearance of	0	52	10	6
12. Overall consideration which type do you like best?	1	58	13	0

* Group I questionnaire did not include these.
X These included in Group III only.

approximately two-thirds of whom had a knowledge of lighting. The viewing procedure was the same as that followed by Group I, with the exception of the darkening of one side of the test area. While the observers were viewing the test installation as pedestrians, the two types of lights were alternately extinguished so that each type could be separately evaluated. At the time of the inspection, the pavement was damp. Rain in the afternoon stopped at about 6:30 p.m.

Group III was a controlled group of approximately 40 lighting engineers, 13 of whom returned questionnaires to assist in the evaluation. The inspection was made at the time that instrumentation was under way, and the group only had the opportunity of viewing the installation traveling eastward from the toll station. The west lane was closed so that the teams taking instrument readings would not have interference from traffic. The pavement was dry and the weather cold and clear.

To obtain the reaction of the traveling public, traffic was stopped at the test strip, and interviewers filled out forms noting driver and passenger comments. Table II lists the questions asked by the interviewers, and the totals in the various columns represent the summation of the replies of Groups IV and V.

Group IV consisted of 132 interviews from through traffic, west-bound. The drivers were questioned just west of the toll area, and this traffic was not stopped and briefed at the east approach to the test installation. Pavement was dry; weather was cold and clear.

Group V consisted of 90 interviews from through traffic, east-bound. This traffic was stopped approximately 1000 feet past the test area, and it *had been briefed* before entering the test area. The briefing consisted of telling the motorists that a lighting study was being made and requesting them to notice the lighting in the test area. Pavement was dry and weather clear and cold.

Due to the comparatively large volume of trucks, special note was made of the drivers' replies. The west-bound (unbriefed) truck drivers indicated

TABLE II — Lighting Evaluation.
Summation of Results of Groups IV through V inclusive.
Test Installation, U. S. Route 1, Old Lyme, Connecticut.

Passenger Cars	109
Trucks	14
Semi-Trailers	99
	222

Did you notice a difference between the two types of lights?

Yes — 204
No — 19

	Mercury	Fluorescent	No Preference
1. Which appeared to have the most glare? (trucks)	43	42	28
Which appeared to have the most glare? (passenger cars)	27	51	31
2. Best pavement illumination	26	145	51
3. Did you notice a difference in shoulder lighting?	10	91	121
4. Which do you feel more comfortable driving under?	51	116	55
5. Do you object to color under lights?	10	7	205
6. Which type do you like best?	49	140	33

that they preferred fluorescent 14 to 1. The eastbound (briefed) indicated a 3 to 1 preference for fluorescent. In the former case the fluorescent installation was last seen, and in the latter case the mercury luminaires were last seen by the truck drivers.

It is recognized that in interior lighting applications, the user, or public, opinion has helped to develop pleasing and comfortable surroundings. This may also be the case with highway lighting. It is to be particularly noted that in response to the purely physiological question, "Which do you feel more comfortable driving under?" the answers were 51 for mercury and 116 for fluorescent. The response to the psychological question, "Which do you like the best?" was 49 for mercury compared to 140 for fluorescent. In contrast to the above, the response to the physiological question by those having experience and knowledge of lighting installations, was 50 for mercury and 22 for the fluorescent system. The response to the phychological question, "Which type do you like best?" was 58 for mercury and 13 for fluorescent. The public, of course, does not have an appreciation of the details involved in such analysis, particularly with respect to the economics involved ,the past history of mercury versus fluorescent light, and the present technical discussion on one type versus the other. Lighting engineers are qualified to pass upon the technical aspects of the lighting installation and we are naturally influenced by their recommendations, but there is a doubt as to whether their opinion should be favored over that of the driving public on the purely physiological and psychological questions. It is to be noted that Group I, for example, voted 27 to 1 in favor of mercury on asphalt pavement brightness, 22 to 3 in favor of mercury on better object silhouetting, and 24 to 4 in favor of mercury on concrete pavement brightness. However, they voted 18 in favor of mercury to 11 for fluorescent under more comfortable driving conditions. Group III voted 8 to 0 in favor of mercury on asphalt pavement brightness, 11 to 0 in favor of mercury on concrete pavement brightness, and 6 to 1 in favor of mercury on better object silhouetting; but they voted 6 in favor of mercury as compared to 6 in favor of fluorescent on more comfortable driving conditions.

Instrumentation

The problem of evaluating the types of lighting installed on the test installation was complicated by the question of instrumentation. Instrumentation requires considerable care and experience in order to obtain accurate readings from which an analysis of the lighting installation can be made. This is especially true in the case of fluorescent installations where the light output increases as the ambient temperature decreases, where the lumen output decreases materially during the seasoning period of the lamp, and where a stabilization period of at least one and one-half hours has to be allowed for operation of the lamp prior to taking any readings. There is also the question of the type of meter to be used for the specific measurement to be taken; the constancy of the calibration; the control of extraneous light; etc.

To insure valid instrumentation by those qualified in this particular field, the State invited various manufacturers to participate, and the following data were collected:

1. The team on luminaire brightness measurements[1] took readings with a portable Spectra-Brightness Spot Meter having an acceptance angle of one-half degree. Readings from the five adjacent poles in the direction of travel were taken at 20-foot intervals in the passing lane starting at Station 81 and progressing towards Station 1, as shown in Fig. 4.

Tables III, IV, and V show the results of these readings.

The luminaire brightness measurements made with the Spectra-Brightness Meter did not check well with the calculated brightness in most cases, particularly in the higher brightness ranges close to the luminaires and in the case of the distant ones. This can be explained by the fact that the meter measured a surface about one inch in diameter at a distance of 10 feet. Measurements of lumi-

TABLE III — Fluorescent Luminaires.
Test Lighting Installation Instrumentation
Spectra-Brightness Meter readings in footlamberts.
30-foot mounting height — 100-foot staggered spacing.
Transverse distance between luminaire centers—49 feet.
Readings taken in passing lane, north side of roadway—15 feet from center of luminaire.

Station	Pole Number 4871	4870	4869	4868	4867
81	2700	2000	1200	720	310
77		2600	1350	850	350
73		2700	1700	960	480
69		2600	1950	1050	400
65		2100	2100	1100	500
61			2100	1250	520
57			2400	1300	600
53			2500	1500	630
49			2600	1700	730
45			2650	1900	800
41				2050	940
37				2450	1150
33				2400	1330
29				2700	1500
25				2100	1800
21					2150
17					2600
13					2800
9					3000
5					2800

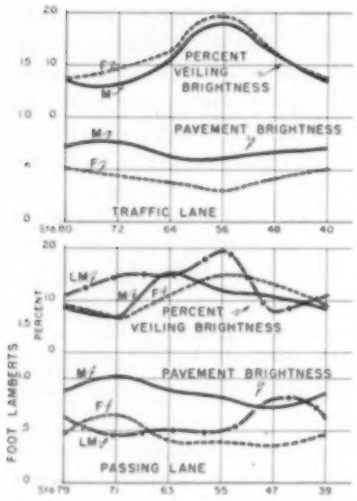


Figure 5. (left) Pavement brightness readings.

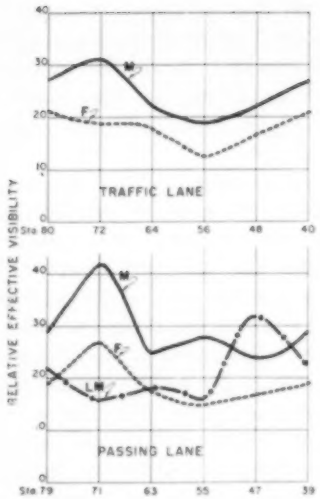


Figure 6. (right) Relative effective visibility.

naires close by could well include small areas of high brightness, and those taken at a distance probably include a considerable part of the dark background.

2. The team on pavement brightness measurements[1] took readings with a Luckiesh-Taylor Brightness Meter. The readings were taken at 40-foot intervals in both the traffic and passing lanes for a 200-foot pole spacing on one side of the roadway. The observer was at Station 1 with the target area at Station 41. The instrument was focused at the feet of an assistant stationed 200 feet away, and readings were then taken of the pavement brightness. The instrument height was approximately four feet. Due to traffic conditions, readings were not taken in the traffic lane under the linear mercury units. The results of these readings are shown in Fig. 5.

The pavement brightness readings were used in conjunction with the calculations to obtain quantitative values for relative effective visibilities in accord with the procedure outlined by Reid and Chanon.[2] Since obstacle brightness readings were not taken, the measured vertical footcandle readings were used and a reflection factor of six per cent assumed, as an average for dark clothing. Fig. 6 shows the relative effective visibility at the stations where pavement brightness readings were taken. These curves include a 20 per cent additional loss in visibility caused by a fluctuating glare

TABLE IV — Mercury Luminaires (Conventional). Test Lighting Installation Instrumentation Spectra-Brightness Meter readings in footlamberts. 30-foot mounting height — 100-foot staggered spacing. Transverse distance between luminaire centers—55 feet. Readings taken in passing lane, north side of roadway—18 feet from center of luminaire.

Station	Pole Number 4902	4901	4900	4899	4898
81	20000	14000	1700	340	100
77		20000	2400	500	160
73		28000	4000	650	200
69		31000	7300	880	200
65		38000	12000	1400	320
61			23000	2600	350
57			30000	4600	550
53			41000	5500	630
49			40000	11000	920
45			41000	19000	1300
41				24000	1300
37				31000	3150
33				32000	7500
29				40000	10000
25					21000
21					31000
17					31000
13					40000
9					40000
5					33000

TABLE V — Mercury Luminaires (Linear). Test Lighting Installation Instrumentation Spectra-Brightness Meter readings in footlamberts. 30-foot mounting height — 100-foot staggered spacing. Transverse distance between luminaire centers—51 feet. Readings taken in passing lane, north side of roadway—16 feet from center of luminaire.

Station	Pole Number 4910	4909	4908	4907	4906
81	10000	5000	1850	730	600
77			2400	800	500
73		7590	2800	810	550
69		9500	3600	1200	730
65		9200	4600	1300	800
61			7200	1800	1050
57			7800	2200	1300
53			7500	2700	1350
49			8600	3900	1700
45			7000	4300	2000
41				6400	2400
37				5050	2900
33				6700	3400
29				7100	4600
25				9100	4600
21					7200
17					7100
13					8000
9					8550
5					7600

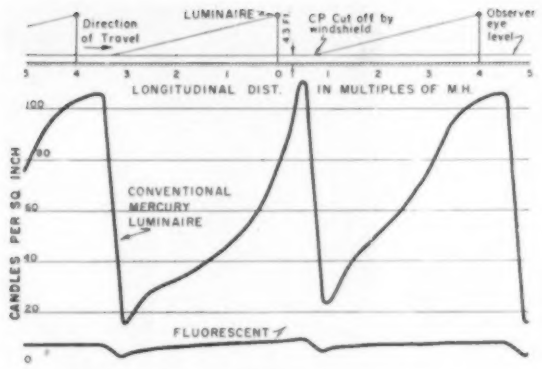


Figure 7. Fluctuating brightness relationship along 1.5 M.H. longitudinal roadway line.

condition when luminaires are shielded from view by the top of a car. In a similar manner to that used by Charles Rex,[4] but using candles per square inch as the ordinate, instead of footlamberts, Fig. 7 shows the fluctuating glare relationships between the conventional mercury and fluorescent luminaires.

The Disability Veiling Brightness was calculated for the four adjacent luminaires in the direction of travel, two on one side of the road and two on the opposite side. The formula used was No. 2-13[3] in the *I.E.S. Lighting Handbook*, and the results of these calculations are shown in Fig. 8. While it may not be significant, it is interesting to note the percentage of Disability Veiling Brightness with relation to the pavement brightness as shown on Fig. 5.

3. Prior to the time that instrumentation was made on the test strip, some very limited measurements of visibility were made, under conditions of specular reflection, using a Luckiesh-Moss Visibility Meter. Target used was a dark grey mat-surface disc of 12-inch diameter with reflectance about 7 per cent. The target was placed in the driving lane near the right-hand curb and located just short of a street lighting unit so that the face of the disc was in shadow. This would be approximately Station 40 on Fig. 4. Measurements were taken from an observation point at a comparable position under the preceding luminaire, which placed the observer approximately 200 feet from the target. Relative visibility readings for this target with the low-range visibility meter were as follows, each the average of 10 individual readings:

	Fluorescent System	Mercury System (Conventional)
Not shielded	1.93	1.77
With shield	2.61	2.45

It is of interest to note that the visibility readings are slightly higher under the fluorescent system despite the fact that the average illumination under the mercury system is somewhat higher. At the time that the readings were taken the pavement was damp, and an elongated light source transverse to the roadway, such as fluorescent, produces broader patterns of reflected pavement brightness contributing to improved obstacle visibility under such conditions. At the points where the readings were taken, the fluorescent lighted portion of the roadway was straight while the mercury lighted portion had a slight continuous curvature. This could mean that pavement brightness was not as much built up in reflection from successive luminaires beyond the nearest one, in the case of the curving roadway.

4. The team on incident footcandle measurements[1] took readings of the footcandle intensity and the angle of incident light from poles adjacent to the point of observation in the passing lane. Because of lack of space, the results of this instrumentation are not recorded in this paper. The incident light readings were taken with a machine which consisted of a mirror and a two-cell paddle, without color correction, located about six inches over the pavement surface. The mirror and the paddle are connected to a Weston No. 756 Meter for reading the light intensity and to a calibrated arc for reading the angles. In operation the machine was pointed toward the light source and manipulated so that the luminaire was centered in the mirror when sighted in through a peep-sight. Fig. 9 shows a picture of the machine in operation at the test installation.

It is intended to use the incident footcandle measurements in conjunction with the pavement reflectance factors now being developed by the University of Illinois. It will be interesting to check the calculated pavement brightness with the actual readings taken at the test installation.

5. The team on footcandle measurements[1] took readings of the horizontal and vertical footcandles along the roadway at 10-foot intervals for a 200-foot pole spacing in both the traffic and passing lanes. Measurements were taken with a GE Type PF 13 cosine-corrected footcandle meter. The results of these readings are shown in Figs. 10 and 11.

The footcandle measurements, in general, follow the predictions made from photometric data for the conventional mercury and fluorescent luminaires, and the instrumentation team expressed gratification at the relation of vertical to horizontal values. It is to be noted that the ambient tempera-

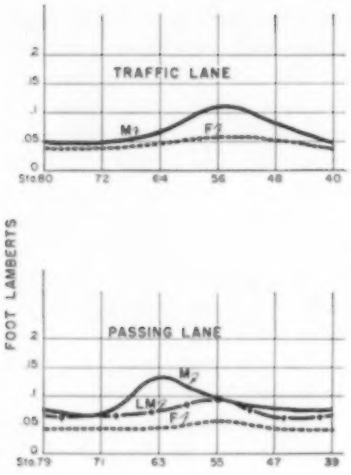


Figure 8. (left) Disability veiling brightness.

Figure 9. (right) Incident footcandle measuring device being operated at the test strip by instrumentation team. Official photograph, Connecticut State Highway Department.

ture of 30° F, at the time the readings were taken, is almost ideal for maximum light output of the fluorescent lamp.

After the instrumentation had been completed, there seemed to be a deficiency in the values for the linear mercury luminaire using the new SH-1 lamp. It has been reported that a manufacturing defect in the first run of the lamps reduced the lamp output from its rated 23,000 lumens to 18,270 lumens. A correction factor of 15 per cent should, therefor, be added to all of the readings taken on the test installation for the linear mercury luminaire to place them on a par with the EH-1 lamp and a factor of 26 per cent to put them on a par with the rated output of 23,000 lumens for the SH-1 lamp.

While it is recognized that there is, at present, no accepted formula for determining discomfort glare in street lighting installations, a proper evaluation of the test installation requires a comparison of this element in the three light sources installed. The empirical formula No. 2-17[3] in the *I.E.S. Lighting Handbook*, for application of the "Borderline Comfort-Discomfort" concept to discomfort glare, is obviously designed for use with interior lighting units. The solid angles subtended by street lighting luminaires are comparatively small, and the index values, when this formula is applied to street lighting, have no absolute significance. However, on the assumption that relationships will be parallel, the values can be used to indicate *relative* discomfort. Since it is not our problem to determine whether any one type of light exceeds the borderline between comfort and discomfort, desirable as this might be, we can, on the above assumption, establish a relative degree of discomfort glare between the three light sources installed.

Fig. 12 shows the amount of discomfort glare, according to the No. 2-17 formula (*I.E.S. Lighting Handbook*) from the four luminaires adjacent to the test station in the direction of travel, *i.e.*, proceeding from Station 81 to Station 1. In applying the formula, the brightness to which the observer is adapted (F), was taken as the measured pavement brightness 200 feet ahead of the station from which the discomfort glare was calculated. It is to be noted that the relative discomfort glare for conventional mercury is calculated at Station 63, and for linear mercury and fluorescent luminaires at Station 55. The reason for this difference is that the calculated Disability Veiling Brightness is greater at Station 63 for conventional mercury and at Station 55 for both the linear mercury and fluorescent. It was assumed that discomfort glare would also be greater at these points, and the calculations were made accordingly.

It is interesting to note that comments from several observers indicate that the borderline between comfort and discomfort may be located somewhere between the maximum value for conventional mercury and the maximum for linear mercury luminaire (see Fig. 12), as the latter was generally considerable acceptable by the viewer and the former as having too much glare.

Photography

On the assumption that a camera could register, to a degree, the light which would strike the eye at the camera location, a series of photographs were taken under the following conditions:

A high-speed panchromatic film with a flat curve in the wedge spectrogram of color sensitivity, *i.e.*, approximately equal color sensitivity to the blues and the greens, was used. All of the film was developed at one time in the same developer at constant temperature.

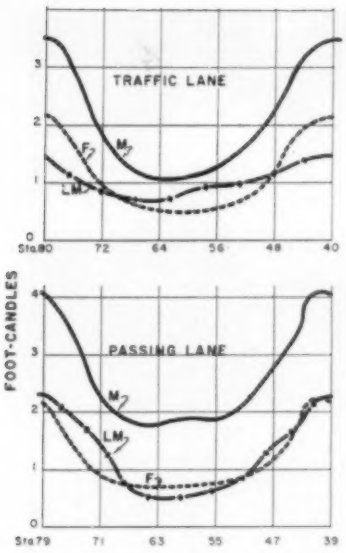
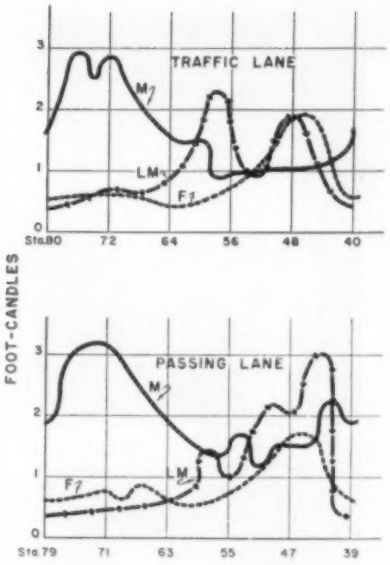


Figure 10. (left) Horizontal footcandles.

Figure 11. (right) Vertical footcandles.



The film used was Ansco Superpan Press with an exposure index of Daylight 125. The film was developed for five minutes in Permadol at 68° F.

The camera used for taking the pictures was, in all cases, a 4 x 5 Speed Graphic with Graflex Optar $f/4.7$ — 135 mm — lens. The camera was mounted on a tripod with the lens 52 inches above the pavement. Lens aperture was $f/4.7$.

Shutter speeds for each sequence were $^1/_{25}$; $^1/_{10}$; $^1/_5$; $^1/_2$; 1; 2; 4; 8 seconds.

Paper was exposed for three seconds and developed one minute in Dektol at 68° F.

Six sequences of photographs were taken, three of which were taken with the luminaire 50 feet ahead of the camera and the other three with the luminaire 50 feet behind the camera. In each of the sequences there are men stationed at 200 feet, 300 feet, 400 feet, and 500 feet in front of the camera, and a black passenger car is parked on the shoulder.

The first three sets of pictures were taken with the camera facing west and the luminaire behind the camera. The results of these pictures showed a dark background behind the obstacles in the mercury (conventional) sequence due to the curve and grade in the roadway. In order to secure a contrasting background for the mercury luminaires, the second set of three sequences was taken with the camera facing east under the fluorescent and conventional mercury luminaires and facing west under the linear mercury luminaires. In all of the second set of pictures, the luminaire was in front of the camera.

The results of the photographic sequences taken at the test installation proved very interesting. Space does not permit including all of the pictures in this paper, but they are available for inspection at this meeting. The photographs taken with the luminaire ahead of the camera, as compared to the photographs taken with the luminaire in back of the camera, indicate veiling brightness since the exposure of the former is considerably longer to render equal discernment. Fig. 13 shows the exposures for $^1/_5$ second, 1 second, and 4 seconds. The sequences also show a different degree of halation around the luminaires and, as was expected, the

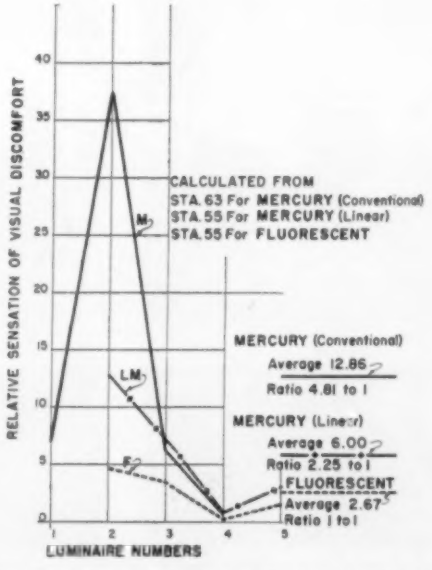


Figure 12. Discomfort glare from four luminaires in the direction of travel.

Figure 13A. Luminaire located about 50 feet in front of camera.

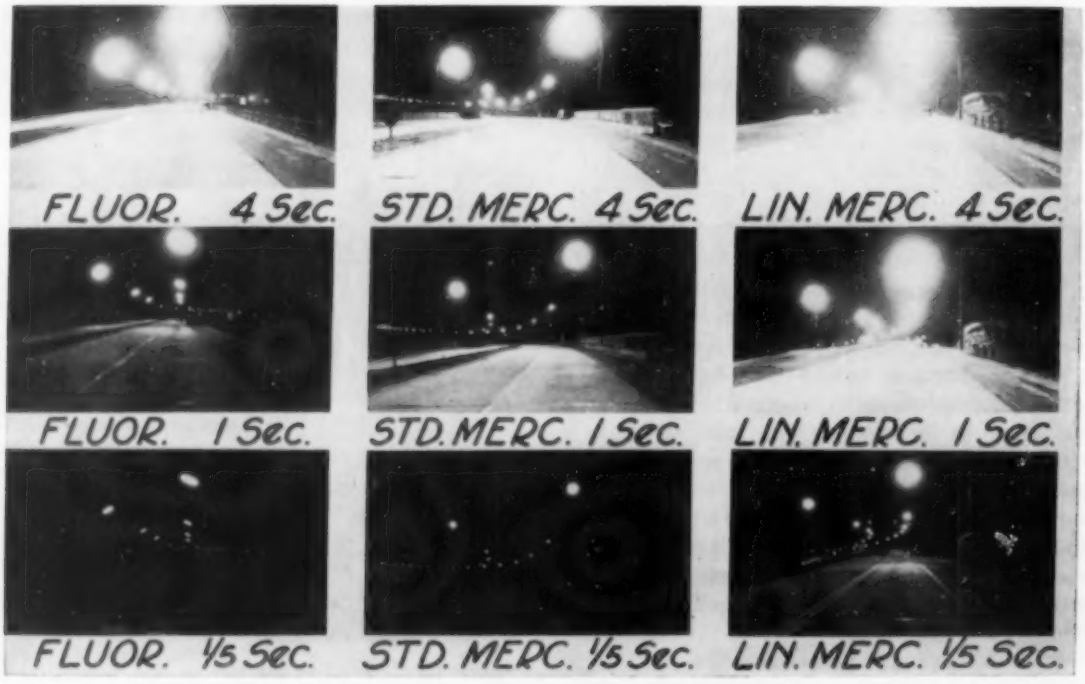


Figure 13B. Luminaire located about 50 feet behind the camera.

photographs for mercury sources show the effect of fogging prior to that of the fluorescent. The author does not known whether this bears any relationship to glare.

Conclusions

The results of the highway test lighting installation would indicate:

1. That the public has a distinct preference for fluorescent highway lighting, but lighting engineers, as a group, seem to prefer mercury. It is to be noted that the linear mercury luminaires were not installed at the time the sampling of public opinion was taken.

2. That vehicle drivers react favorably to well-lighted highways since it was noted that trucks and passenger cars switched to low beam headlights on entering the test area. Many of the trucks used only their parking lights and did not reduce their driving speed.

3. That in some types of highway lighting the low brightness luminaires appeal to the driving public despite the fact that pavement brightness may be lower when they are used.

4. That a linear light source reflects an advantage under wet pavement driving conditions since it provides ribbons of light as compared to the narrow beam of light from a point source under conditions of specular reflection.

5. That the low brightness of linear luminaires tends to reduce the contrast against a black surround such as exists in highway lighting.

6. That instrumentation, to the extent accepted as standard at present, is not the sole criterion for good highway lighting.

At the date of this writing, the State of Connecticut has not made a decision as to the type of lighting to be installed on the Connecticut Turnpike, but it is hoped that at the time of this presentation such information will be available.

Acknowledgments

The author acknowledges his indebtedness to the many friends who advised and assisted in the preparation of this paper.

References

1. One representative from each of the vendors participating was assigned to each of the instrumentation teams and the readings verified by all of them. All were in agreement as to the test reading locations and the methods used. At the time that readings were made, the fluorescent luminaires were lamped with 4-F100T12/CW-RS lamps (21,400 lumens); the conventional mercury luminaires with 1-H400E1 lamp (21,000); the linear mercury luminaires with 1-Sh1 lamp (23,000 lumens).

2. Reid, Kirk M., and Chanon, H. J.: "Evaluation of Street Lighting, *Transactions of the Illuminating Engineering Society*, Vol. XXXIV, p. 1209, (December 1939).

3. *I.E.S. Lighting Handbook*, 1954, Second Edition, second printing, Section 2, Light and Vision.

4. Rex, Charles: "Luminaire Light Distribution Principles," Figure 14, ILLUMINATING ENGINEERING, Vol. L, p. 602 (December 1955).

DISCUSSION

WARREN H. EDMAN:* Several street lighting people from Holophane, including myself, did have the opportunity last summer to inspect this test installation. Unfortunately, I was not able to attend the first group inspection of the street lighting engineers. I wish first to acknowledge and commend the State of Connecticut and the author for recognizing the importance of highway lighting in undertaking this test project.

I am a bit puzzled as to how and why the author arrived at his conclusions from two different sets of questions, one for the lighting group and the other for the public.

It should be noted that the set of 15 questions asked the lighting group were all positive, quite specific, and well understood. On the other hand a different set of seven questions asked the public were quite general, some ambiguous, and not clearly understood. My point is not one of objection to the questions but rather that no direct or real comparisons can be made between the two groups.

Let us take for example the question of color. Surely, had this non-technical question been put the same way to both groups the response could have been expected to be in close agreement. However, the lighting group were asked for a preference—the vote being 37 preferred fluorescent, 15 preferred mercury and 19 had no preference. On the other hand the public was asked in a negative manner to vote their objection instead of their preference. Obviously, no comparison can be made since 92.4 per cent of the public had no objections to either fluorescent or mercury.

Another of the many points which impressed me was that the author, throughout his paper, has emphasized comfortable and pleasant lighting. As related in this test installation, this would seem to be synonymous with discomfort glare. He goes on to conclude that the public preferred the fluorescent luminaires. Contradicting this conclusion, I call attention to his table that 93 voted fluorescent to be more glary, whereas only 70 voted mercury to be more glary. The trucking group which has been singled out as a special group, voted about equally; that is, 42 fluorescent, 43 mercury, and 28 had no preference.

The only statistical support for his number one conclusion, "that the public has a distinct preference for fluorescent highway lighting," apparently comes from the favorable vote on the very general question, "which type do you like best?". It should be remembered that a through traveling public, generally in a hurry to reach some distant destination, would have little or no interest or patience in such a local activity on a highly technical subject about which they know very little. Consequently, they become responsive to that which strikes them as the most popular and most logical answer so they can be on their way. Surely, a great many of them would be in a frame of mind to avoid saying anything which might lead to prolonged discussions and questioning. Then, fluorescent, being the "latest" in light sources, would quite logically receive a favored response.

The author then continues, "but lighting engineers as

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a group seem to prefer mercury." This latter statement, in view of the overwhelming agreement of this group appears to be as much understated as the first part appears to be overstated. All lighting engineering groups, including 10 non-lighting people, are at least consistent and not as contradictory as the uninformed public. However, it must be pointed out in all fairness to the public that they were more or less taken by surprise, whereas the lighting engineers were not. They voluntarily accepted the task of evaluating the different lighting systems. About all that can be deduced from such a limited and hasty public poll would be to prove that, as in the past, briefing of the participants, technical or non-technical, is necessary and all variable factors and circumstances must be carefully controlled if any credence is to be placed on the results.

In conclusion number 3 the author states that the "low brightness luminaires appeal to the driving public despite the fact the pavement brightness may be lower when they are used." It is assumed the author is referring to the fluorescent luminaires. Assuming that low brightness means less discomfort glare, why did the public vote the fluorescent luminaires installed to be more glary than mercury? This, again, seems contradictory.

Let me clarify that we are here comparing one specific type of fluorescent luminaire against one specific type of mercury luminaire for a specific application. By no means should one draw final conclusions for or against on the basis of the light sources themselves. It should be pointed out that the source is only important component and that the luminaire is fully as important, and perhaps, more so in this particular appraisal. I also should like to point out that the fluorescent lamp being relatively new to street lighting has not, as yet, had the benefit of advanced optical design and control such as has been developed for mercury and filament sources over many years. For instance, the present fluorescent luminaire designs have higher candlepower at the higher veiling glare angles above 80 degrees. This higher candlepower tends to be accumulative so that the total "system glare" becomes more pronounced with increased length of the installation. The "distraction glare" also becomes more pronounced. I have confidence that these present objections will not long remain unsolved. So let us not come to hasty conclusions that the future possibilities of the fluorescent lamp should stand or fall on this particular test installation.

Another important factor which has been given little or no consideration is that of "source size factor." Let us not ignore it. Admitedly, more data is needed on this to find out its degree of importance as related to the end product of visibility distance and comfort.

Without going into further detailed comments, I should like to conclude with the following questions:

(1) No reference was made to the importance factor of comparative visibility distances of the different systems. Is this not perhaps the most singularly important factor in highway lighting as well as street lighting? Surely, the first requisite of any artificial lighting system is to provide visibility to first recognize objects ahead. Then the factors of clarity of recognition, comfort and the other secondary factors must also be considered.

(2) Did the reversal of traffic direction or the briefing *vs* non-briefing of the general public, or both account for the great difference in the truck drivers' voting ratio on the point of "preference for fluorescent"? What was the specific question asked?

(3) Why does the author seem to give less credence to the more comprehensive and consistent evaluations of the lighting engineering groups than to the limited, less comprehensive, inconclusive and contradictory evaluations of the public?

R. M. SWETLAND:* We wish to emphasize only one phase of the evaluation of this highway lighting test installation. As is generally known, roadway visibility and seeing (including the comfort factor) cannot now be conclusively measured, nor computed, by existing devices or methods.

Consequently, we feel that the author of this paper, and his State Highway associates, has rendered a distinct service to all interested in roadway lighting by including in their study of this test installation, an opportunity for public driver opinion and reaction as to "how they like it." We feel that the results tabulated in Table II are most significant and meaningful.

(1) "Which do you feel more comfortable driving under"—over 2 to 1 favoring fluorescent.

(2) "Which type do you like best"—3 to 1 favoring fluorescent.

(3) "Which has best pavement illumination"—over 5 to 1 favoring fluorescent.

We predict that this public opinion and reaction may well be indicative of the *trend* in overall roadway lighting practice in this country.

F. D. WYATT:** The Connecticut State Highway Department, Commissioner Argraves and George Nagel are to be commended for making these tests of the lighting installations, the careful method of making the tests, and for publishing the test data secured.

There are several comments which I would like to make regarding the test installation, the test data and the conclusions drawn from both tests and observations.

(1) It should be pointed out that the fluorescent installation was placed in the most favorable position, namely with lighted sections at either end of the fluorescent section. An automobile driver's eyes thus become light adapted, so that the veiling sky glare from the units will be less pronounced.

The mercury units at the east end of the test installation is entered from an unlighted highway, thus the drivers' eyes are not yet light adapted, so that the veiling glare effect from the luminaire will be more pronounced. Also the center of the mercury section is over the top of a hill, with the angle between the line of sight and the glare source at the luminaire smaller than usual, so that the veiling glare from the luminaire appears greater than normal.

These factors should be considered in making an appraisal of the two installations.

(2) There is a question as to the validity of the reading and the inferences and conclusions drawn from the brightness readings. With an acceptance angle of ½-degree at certain distances the entire projected glass area would be covered by a ½-degree spot, whereas only a portion of the fluorescent luminaire would be included in the field. Dr. Hopkinson in his address before the Boston Conference pointed out that the total luminous area was important in measuring the veiling glare. It would appear, therefore, that the instrument measurement does not correctly interpret what the eye sees.

(3) In any street lighting installation it is necessary to consider the economics of the job. After inspecting the test installation, taking a number of check readings, and reviewing the previous test data, I made a number of calcula-

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tions of various factors involved. For equal illumination on the street the construction costs for fluorescent will be over 250 per cent that of mercury lighting. This can be readily understood when it is seen that the coefficient of utilization *for this installation* is 22 per cent for fluorescent and 58 per cent for mercury. The accumulated system glare from the present fluorescent installation is already high, and would be much more severe with sufficient fluorescent units to give equal illumination.

(4) The position of the skilled engineers and the traveling public seems to be reversed in weighing the observers' opinions. The lighting engineers were predominantly in favor of mercury lighting. The reaction of the public depends on many factors, such as direction of travel, method of asking questions, and the intriguing interest in something new. It would not appear that the testimony justifies the conclusions. No reference is given to the objection of truck drivers to the daytime reflection of sunlight from the large fluorescent luminaire surfaces.

(5) At the Boston Conference there were several papers presented, describing new developments in fluorescent lamps: (a) new low pressure fluorescent lamps of 1600 to 2500 lumens per linear foot, which will permit smaller luminaires with much better optical control than present-day luminaires; (b) improvements in high-pressure fluorescent lamps with a promise of 65 to 75 lumens per watt soon, and 80 to 90 lumens per watt later. These lamps use current well-designed fixtures with efficiencies around 75 per cent and utilization coefficients of well over 50 per cent.

In view of these developments, it would appear that the present large fluorescent luminaires with low effective use of light on the pavement are due to drastic redevelopment.

R. E. BALLARD:* Mr. Nagel and his associates deserve all the credit possible for this analysis of a very controversial subject. Since there is a complete lack of factual data to base such an analysis on, there would naturally be some phases that would raise questions.

The evaluation procedures and their results point up a marked difference of opinion between the expert group and the driving public. Mr. Nagel comments in his paper that the driving public "does not have an appreciation of the details involved in such analysis, particularly with respect to the economics involved." The purpose of the test is to determine which light source is considered best for driver comfort and safety. It is my opinion that any analysis of this type in its initial stages economics should not be included and should have no place in scientific evaluation.

The instrumentation section of Mr. Nagel's report emphasizes the complete lack of available formulae or evaluating equipment to use in arriving at either an indisputable decision or conclusion. Fig. 6 on Relative Effective Visibility indicates that point source standard mercury has much higher visibility than either fluorescent or linear mercury. However, in paragraph 3 of that same section, tests performed with the Luckiesh-Moss Visibility Meter indicate that fluorescent has better visibility. I realize that Fig. 6 was derived from the Reid-Chanon formula, and that the Luckiesh-Moss system only includes specular reflection. However, the disparity between the two does not help an already confused situation.

Fig. 7 indicates the fluctuating brightness relationship between fluorescent and standard mercury luminaires. Mr. Nagel states that there should be a minimum flicker effect in good highway lighting. Fig. 7 indicates a very marked flicker effect for standard mercury.

At this point, I would like to ask Mr. Nagel some specific questions.

(1) Why is the economic aspect of highway lighting considered important when the primary purpose of the test strip is to determine the best luminaire and source for driver safety and comfort?

(2) Why isn't linear low-brightness mercury included in Fig. 7? Should it not be?

(3) It is agreed that there is additive brightness with a fluorescent installation which results in a higher total brightness when several luminaires are in the visual field. Fig. 7 indicates, as stated above, a very constant brightness for the fluorescent system compared with a marked contrast in brightness for standard mercury. Both the relatively even high brightness of fluorescent and the marked flicker or shutter effect of standard mercury are fatiguing under prolonged exposure. Which is the lesser of the two evils?

(4) Would not a larger public sampling, which included the low-brightness linear mercury, be of more value than the present one, which does not include linear low-brightness mercury?

In conclusion, my sincere congratulations to Mr. Nagel and the Connecticut State Highway Department for making possible this much-needed study of highway lighting.

W. B. ELMER:* The author is to be complimented for his recognition of the need for and value of continuous highway lighting on heavily travelled high-speed highways. Mr. Nagel also deserves the highest compliment for the skill, insight and detailed care with which he has analyzed and presented this intricate subject, and for his receptiveness to progressive trends in his search for the best solution to his problem. Our industry can be grateful for the attention given to this phase of highway construction by highway engineers and also for the considerable expense undertaken by the State of Connecticut in seeking technical data not otherwise available and the very substantial stimulus that this program will give to the entire field of highway lighting.

In the paper, Mr. Nagel quite properly furnished a very brief description of a new form of street luminaire designated as the "linear low brightness" mercury type. Inasmuch as the manufacturer of the ten prototype units installed on the test strip has not yet issued complete technical data, a few items of basic information are here recorded to assist in evaluation of the results contained in the paper.

The LLB (linear low brightness) luminaires are enlarged crescent-type reflectors, four feet in length, giving the nighttime impression of a horizontally elongated and uniformly bright light source. In each luminaire the brightness of the vertical burning lamp is tempered to the point of visual comfort by enclosure within a white glass diffusing globe.

This new luminaire (adapted to I.E.S. Types I, II, III and IV and furnished with either standard or unbalanced distribution for one-way traffic) was installed on the test strip with Type III distribution. The active relector surfaces are highly specular, non-prismatic, and measure approximately 400 square inches in main working area. The reflector brightness is extremely uniform and averages around 18 to 20 cp per square inch with maximum of 25, compared with averages of 50 to 70 and maxima of 350 to 400 cp per square inch for conventional mercury luminaires.

The LLB luminaires are stated in the paper to be of the

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"open bottom type," however, the enclosing glass globes rules them out of the "open" classification. The plastic reflector sides are clear in the lower areas and extend well below the globe, giving lateral protection to the lamp substantially exceeding that of conventional enclosed luminaires.

Observer Evaluations. The evaluation of the lighting by observers was disappointing because of (1) the conflicting results obtained and (2) the meagerness of data relative to the LLB luminaires, which were not developed in time to participate in the visual evaluation program.

The author discounts the observations of those skilled in lighting in favor of the opinion of the public, on the ground that the skilled observers are swayed by economic and other factors not present in the consideration by the public. This discusser suggests that the public is inclined to express preference for that type of lighting which is most conspicuous, and that the public opinion should be heavily discounted. On only one main point did the skilled observers and the public agree completely—that the *fluorescent luminaires glare more than the old-style mercury.* From Tables No. IV and V, we discover that there is reported:

	More Glare While Driving Under Fluorescent	Old-Style Mercury
Skilled Observers	40 (63.5%)	23 (36.5%)
Public	93 (57.1%)	70 (42.9%)
Total	133 (59%)	93 (41%)

This result is amazing because the fundamental purpose of fluorescent lighting is the reduction of glare. The lack of optical control and low efficiency are supposedly accepted and discounted as a price willingly paid to escape the harsh glare characteristic of conventional high-brightness luminaires. This specific verdict from the Connecticut Highway seems to contradict and upset the fundamental *raison d'etre* of fluorescent street lighting. It is suggested from this discusser's personal observation that the tipped fluorescent luminaires on the far side of the highway combined with their lack of horizontal cut-off contribute substantially to their greater overall glare.

That public observers ascribe more glare to the fluorescent installation while at the same time expressing an overall preference for it supports the supposition that the public is easily confused and perhaps unable to evaluate clearly its own true preference. This result should not be construed as condemning fluorescent lighting for its normal application —white-way lighting.

Instrumentation—General. Four appreciable errors have been recognized in the instrumentation data presented in the paper, as follows:

(1) The new 400-watt SH-1 color-improved mercury lamps used in the LLB luminaires were subnormal in lumen output by 15 per cent.

(2) The old-style mercury lamps were spaced 8 per cent closer together than the other types.

(3) The ambient temperature of 30F during the tests caused the fluorescent luminaires to read 32 per cent greater in light output than the standard values taken at 77F.

(4) The Weston cell used in the incident light tests was not color-corrected and read 11 per cent low when measuring light under the E-H1 and SH-1 mercury lamps.

All data used in the following discussion have been altered in accordance with the above corrections.

Instrumentation—Spectra Brightness Readings. The luminaire brightness readings made with the Spectra Brightness Spot Meter are reported with very brief discussion. Because the ½-degree acceptance angle of this meter agrees very

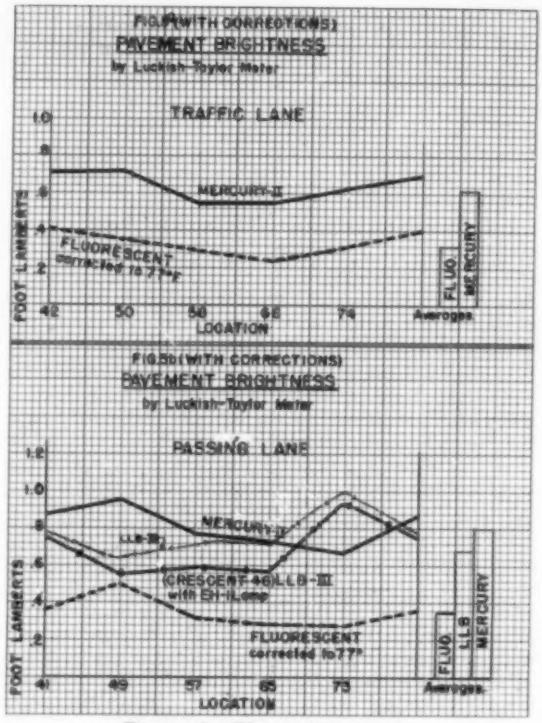

Figure A (Elmer discussion).

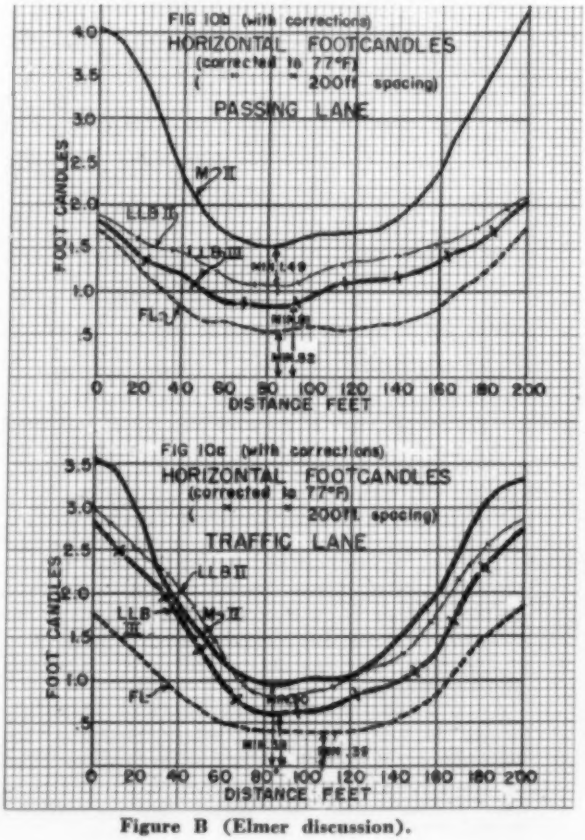

Figure B (Elmer discussion).

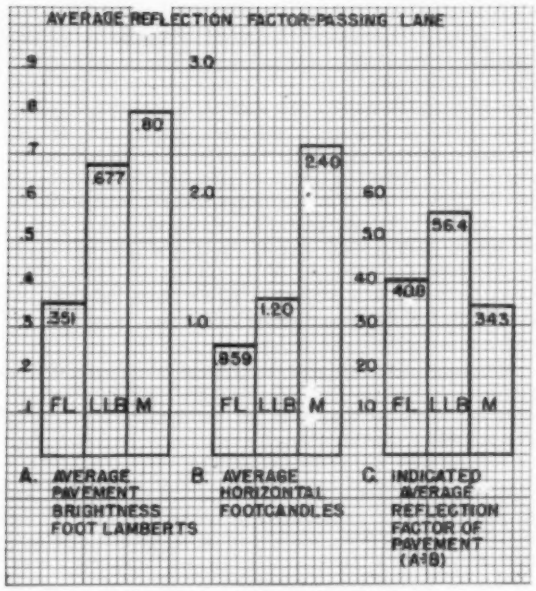

Figure C (Elmer discussion)

roughly with the acceptance angle of the sensitive rod-free area within the foven of the human eye, it seems likely that these meter readings can be regarded as a crude measure of the discomfort glare produced during direct fixation of the eye upon the luminaire, such as occasionally occurs in the night environment and more often with the more distant luminaires. Although the luminaires are seldom viewed directly during night driving, an occasional occurrence can completely disable the eye temporarily if the brightness is too high, resulting in a serious danger to the viewer if he happens to be driving rapidly. This could easily occur to drivers in open cars with no shielding visors. This factor alone should cast serious doubt on the advisability of applying "pin-point mercury" for highway lighting. Momentary blinding of pedestrians or highway personnel on foot at night from this cause could also be extremely hazardous. The threshold between excessive and acceptable *discomfort* glare is subsequently assessed by the author as lying somewhere between the effects produced by the mercury and the LLB luminaires. This discusser accordingly suggests, upon consideration of the data given in Tables I, II, and III, that some value between 15,000 and 20,000 footlamberts average brightness in any ½-degree cone of vision might well be considered as the maximum permissible limit for any street and highway lighting luminaire.

Instrumentation—Pavement Brightness. Corrections for all applicable errors have been applied to the pavement brightness readings, and Fig. 5 has been re-plotted to show the results after these corrections have been made. The pavement stations at which the original readings were made do not agree with the stations given on the author's curves and appear to be given in reverse order. The mercury luminaires used on the test strip are Type II whereas the LLB are the wider Type III distribution. In order to provide an equal comparison, the LLB curves for Type II distribution have been estimated and plotted on the same graph.

In Fig. 6, so-called Relative Effective Illumination is shown worked out on the basis of the Reid-Chanon procedure. It is not known whether the new large low-brightness luminaires produce less veiling glare per unit of illumination at the eye than the older small high-brightness luminaires of equal candlepower distribution characteristics. It seems probable that this would be found true. The Reid-Chanon procedure makes no discrimination whatever in this respect.

The new visibility meters now under development give strong promise of future ability to measure Relative Effective Illumination with the luminaire size taken into account.

The same question is applicable to Rex's work upon which Fig. 7 is based, and to the formula used for disability veiling glare shown in Fig. 8. Referring to Fig. 7, an explanation of how and why candles per square inch were substituted for footlamberts would be helpful.

Usable pavement reflection factors are still being actively sought with which to check by calculation the observed pavement brightness values. Until these data are received and analyzed, the incident light readings can be of little value except as a double check on the horizontal footcandle readings, which has been done with a fair degree of success.

Instrumentation—Footcandle Illumination. The horizontal footcandle readings were corrected and replotted as shown in revised Figs. 10. Here again, comparative estimated curves for the LLB luminaire with Type II distribution have been shown. Neither the distribution curves nor the incident light readings could be reconciled with the horizontal footcandle values, unless the data for passing lane and traffic lane were interchanged. Consequently, these have been replotted in this way.

If the average pavement brightness values are divided into the average horizontal footcandles (passing lane), the resulting values can be regarded as a composite average of the reflection factor of the pavement under the luminaires. Differences in overall reflection factors can be ascribed to the nature of the light distribution characteristics of the several luminaires. It will be noted that the LLB luminaires achieved the highest average reflection factor, thereby utilizing its light to the greatest advantage of the three types of units tested. This effect is borne out by the photographs given in Fig. 13 of the paper which demonstrate excellent visibility under the LLB luminaires.

In conclusion, I would like to emphasize the second conclusion of Mr. Nagel's paper. The frequency with which both truck and passenger car drivers switch to parking lights while driving through the test strip brings realization that here is a solution to that classically vexatious and chronic problem—how to eliminate headlight glare. Apparently well-lighted highways will truly be the long-sought answer! This posibility is so exciting that many questions immediately arise which might be answered by further studies on the test strip. For example, what are the threshold values of illumination for safe driving with parking lights; will drivers spontaneously turn their lights down below this value; what precautions are needed at dark exits under such conditions and to what extent is night-time use of the highways increased by such lighting. We hope that the test strip in Connecticut can continue to be a source of such tremendously useful and valuable information.

K. M. Reid and D. A. Toenjes:* The test installation described in this paper is surely of great interest to all street lighting engineers. Mr. Nagel's paper will be much appreciated as a progress report, particularly describing the various techniques by which the effectiveness of different

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lighting systems can be evaluated or compared. Some of these techniques are relatively new and further refinement will doubtless make them more useful as engineering tools.

In the description of the test installation, the term "linear mercury" is used in referring to one design of luminaire. In the footnote it is described in further detail. Would not a more realistic term be something like "partially shielded non-refractor" units? This would reserve the use of the term "linear" for really elongated luminaires, such as the fluorescent. The difference does not become important until the conclusions. There Topic 1 uses the term "linear" to refer to the open-type units, and Topics 4 and 5 are general statements about pavement reflectance patterns under linear light sources, and contrast of such sources against their surround. While this open-type mercury unit is intermediate in length between the conventional mercury and the fluorescent units, its reflected pavement brightness patterns on wet streets are necessarily more restricted than with the longer fluorescent luminaires. The objection to describing as "linear" a luminaire of this design is the implication that it is on an equal basis with the lower-brightness, more elongated, fluorescent luminaires.

In the descriptions of observer and driver reaction, supplemented by Table I, it is very likely that the experienced observers who participated in the tests carried strong convictions in advance as to the superiority of one type of lighting or another, or as to specific comparisons in which a definite difference might be expected. The author has stated, "Lighting engineers are qualified to pass upon the technical aspects of the lighting installation and we are naturally influenced by their recommendations, but there is a doubt as to whether their opinions should be favored over that of the driving public on the purely physiological and psychological questions." Perhaps the statement in the conclusions, to the effect that lighting engineers prefer mercury, as a group, should be re-worded to apply only to the *particular* lighting engineers who participated in these comparisons. Has Mr. Nagel had occasion to ask the appraisal of a group of college educators who might teach courses in illumination but would not be likely to have any pre-formed design preferences?

There is one broad statement of lighting objective that we have offered before. The discussion of this paper indicates that it would bear repetition. The comment: In roadway lighting, *comfort* is important. Now that our lighting technology has carried us from barely seeing to safe seeing, *lack* of comfort remains the major deficiency of most of our roadway lighting systems. In long continuous installations of roadway lighting, comfort becomes of paramount importance.

GEORGE A. NAGEL:* We are obliged to the discussors of this paper and feel honored that men of their standing in the profession should contribute their time and effort to prepare written discussions. Unfortunately, the preprinting of the paper was delayed so that the discussors had relatively little time for their review, and this may account for the fact that the author considers some of the questions as having been answered in the paper.

Mr. Edman seems to object strenuously to the author's placing greater credence in the public reaction than that of the experienced lighting engineers. The author believes this is quite adequately covered in the paper under *Evaluation*, sub-paragraph "Observer and Driver Reaction." It is to be regretted that several questions were asked of the public which they obviously did not understand. The question of glare is not well understood by many engineers, and therefore it is unreasonable to expect the public to answer this question intelligently; and to use such answer for the purpose of comparison with the engineer's evaluation is improper since the engineer's conception of glare and that of the public are not necessarily the same. We suggest again that the two important questions asked were, "Which do you like best?" and, "Which do you feel the most comfortable under?" It seems, as Mr. Swetland stated in his discussion, that the answers to these questions are most significant and meaningful. We should not lose sight of the fact that the public is paying the bill for street lighting and, also, that the lighting engineer's thinking is guided by public acceptance of his designs.

We cannot agree with Mr. Edman that the results of the public evaluation are less comprehensive, less inclusive, or more contradictory than those of the lighting engineering groups. We feel that their answers to the questions they understood were direct and unqualified.

Mr. Edman states that no reference was made to the important factor of comparative visibility distances of the different systems. We would like to call to his attention that the paper outlines a very definite attempt to secure a comparison of the depth perception by means of photographs, and we feel that the pictures taken do bring out the factors of clarity of recognition, comfort and threshhold discernment.

With regard to Mr. Edman's question regarding the reversal of traffic direction and the briefing *versus* non-briefing as having an effect on the drivers' voting ratio, we would answer that. . . *it did*. The questions asked of the driving public are listed under Table II in the paper, and in addition, it was suggested to the drivers that they should state "no preference" unless they had a very distinct preference for one type of lighting *versus* the other. The results showed that we had 24 per cent "no preference" for the non-briefed, but only 9 per cent "no preference" for the briefed. The overall results of the truck drivers voting ratio shows 71 per cent for fluorescent and 5 per cent for mercury in the non-briefed and 68 per cent for fluorescent *versus* 23 per cent for mercury in the briefed. This would indicate that the briefing reduced the "no preference" answers.

With reference to the comments by Mr. Wyatt, we do not agree that the mercury installation was placed at a serious disadvantage as compared to the fluorescent installation. At the time of the driver evaluation there were only two types of luminaires installed, *i.e.*, the conventional mercury and the fluorescent. Under this condition the conventional mercury had a long tangent which permitted evaluation on a straight-a-way. The decision to install the luminaires as they are on the test strip was determined by the lengths of black-top and concrete pavement available, and the division was made so that we could evaluate the two types of lighting on the different pavements.

We agree with Mr. Wyatt that the validity of the readings taken with the Spectra Brightness Spot Meter are questionable since, as pointed out in the paper, the area included in the readings varies. Mr. Wyatt suggests that the conclusions drawn from the brightness readings are in question, but we call to his attention that we drew no conclusions from these readings.

With regard to the economics of the installation, this did not enter into the evaluation of the fluorescent *versus* mercury lighting. It does, of course, become a major consideration when a decision is made as to the type of lighting

*Author.

to be installed on a particular project. In arriving at such decision, however, the evaluator should not decide on the basis of footcandles alone, but should consider the visibility, the seeing, and the comfort which the different types of lighting provide.

It is conceded that considerable development will be undertaken in the fluorescent lamp, but it, by no means, is definite that the new lamp will be ready for street lighting application in the near future.

With reference to the questions by Mr. Ballard, the linear low brightness luminaire was not included in Fig. 7 since the information on the unit was not available at the time that the graph was made.

As to which is the lesser of the two evils, *i.e.*, the flicker effect of standard mercury versus the relatively even brightness of the fluorescent luminaire, we would like to call to Mr. Ballard's attention that a half-mile installation of each of these types of lighting indicated that the additive brightness of the fluorescent installation was not objectionable. We believe that the installation of one-half mile of fluorescent lighting, as was installed on the test strip, should be adequate to evaluate a continuous installation as regards the cumulative effect of the luminaire brightness.

We agree that a larger public sampling including the linear low brightness mercury luminaire would be of more value than the present one, which does not include the latter; but, on the other hand, it must be realized that the time was relatively short in which a decision concerning the Connecticut Turnpike had to be made, and such an extensive evaluation could not be undertaken within the time allowed. There is also a question as to how extensive such a test should be, since available luminaires have different characteristics, and it was not the intent of this test installation to evaluate luminaires and their cost, but rather to evaluate the different types of lighting using representative luminaires.

Regarding the discussion by Mr. Elmer, we cannot agree that there are four appreciable errors in the paper. We would like to point out that the object of this paper is to report conditions exactly as they were recorded without any correction based on assumed conditions.

It has been reported that the 400-watt SH-1 color-improved mercury lamp used in the LLB luminaire was subnormal in lumen output by some 15 per cent. We have not, to date, been favored with any photometric data to substantiate this statement, although we have every reason to believe that it is correct. This condition, however, does not represent an error in the paper.

The statement is made that the old-style mercury lamps were spaced 8 per cent closer than the other type. This condition may exist on the inner edge of the curve which occurs on the roadway in the test strip installation, but this only applies to four or five luminaires. Check measurements taken in the field show that the great majority of the luminaires are spaced at 100-foot staggered spacing.

Regarding the ambient temperature existing at the time of instrumentation and the propriety of correcting it to a standard value of 77F, we would like to call attention to the fact that a temperature reading of 30F was noted at approximately ten o'clock in the evening, but the temperature was falling; and we have no definite knowledge as to the exact ambient temperature at the time that the instrumentation was made under the fluorescent luminaires. It would be presumptious on our part, therefore, to make a correction in the paper on the basis of an assumed temperature.

Since the results of the incident light tests were not included in the paper, there is no error due to the omission of the 11 per cent correction factor for color.

We appreciate Mr. Elmer's comments and his corrected curves, which, we believe, will probably be of considerable value to all interested parties wishing to apply his suggested correction factors.

Regarding Mr. Elmer's question as to the reason for using candles per square inch rather than footlamberts in Fig. 8, this was only done because the candle per square inch data was readily available.

We are obliged to Messrs. Reid, Toenjes, and Swetland for their discussion and are happy to note that they agree in general with our findings.

Committee Lists in April

The revised listing of the Standing, General, Task and Technical Committees for the year 1956-1957 will appear in the April issue of ILLUMINATING ENGINEERING.

Quiet good taste—
Restraint—
Confidence—
These are the values represented in the design of this

MODERN BANK

PROFOUND philosophical comment could be made in many an architectural paper, on twentieth century changes in building design, and what they represent in basic human values. No longer, for example, must banks be enormous monuments to financial solidity. Opulently decorated to epitomize great wealth. Loftily constructed to suggest remote, awesome, high-level transactions. Such design, and the massive chandeliers which lighted them, reflected attitudes of the times in the banking business.

New concepts in bank design express quite different values. In the Bank of Georgia (Atlanta) shown, the deliberate architectural intent has been toward a quiet commercial interior. Lighting has been carefully planned to abet this, and at the same time to fulfill the functional needs of the people who work there and the customers who bank there.

. . . In the banking lobby shown above:

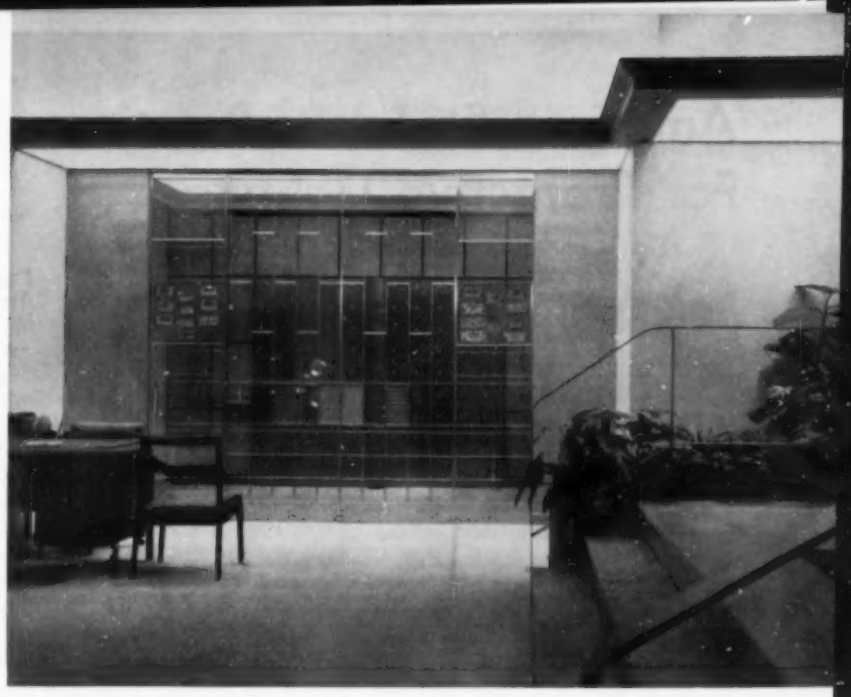
A louvered ceiling over the tellers' booths, with continuous cove at the lobby edge, provides 150 ft-c over the working desk area, and at the same time enhances the architectural design. The louvered area, 5 feet by 40 feet, is a custom-built drop ceiling to provide a plenum for four rows of two-lamp slimline units. The cove, using continuous single 40-watt fluorescent strip, "washes" the curtain wall and ceiling to relieve brightness contrast from the high-level louvered ceiling section. A similar louvered ceiling design emphasizes the vault area in the rear. This section is 3 feet by 12 feet; cove lighting at the edge reduces the contrast.

Between the brass grill work in from the vault and vault door, a continuous cove, with four concealed spotlights serves to highlight the brass vault doors and leather paneling bordering them. Straw-color filters are used over these spots, to bring out the color of the brass and leather.

Ornamental spun brass lamp housings over the check-writing counter provide 50 ft-c at this area. For general lighting in the lobby, 300-watt recessed units are used, with black square concentric louvers having brass trim. Any possible glare from these fixtures is effectively minimized by the indirectly lighted ceiling, perimeter lighting of the walls and the white terrazzo floor.

Designer — Allan L. Ferry, Interior Designer, Atlanta.
Lighting — Hugh Saussy, Lighting Consultant, Atlanta.
Electrical Contractor — Whitehead Electric Co., Atlanta.
Finishes — Ceiling, 12x12 acoustical tile; floor, white marble terrazzo; walls, plaster painted pastel colors; screen partitions and fixture metal, dull brass; paneling, leather or walnut plywood.

This installation won, for Hugh Saussy, second prize in the 1956 contest for My Most Interesting Lighting Job conducted by the Georgia Section of I.E.S.



. . . In the foyer and vault area:
A custom-built drop ceiling, 3 feet by 12 feet, and a smaller section over the planter, serve the dual purpose of decorative coordination with the room's design and high-level lighting at the vault doors. An additional cove between the protective grill and the vault, contains concealed spotlights with straw-colored filters to enhance the brass and leather paneling of this area.

. . . In the vestibule and offices:
Booths for examining safe deposit boxes (below left) are individually lighted by wall-mounted brackets of similar design to office luminaires. The edge of the entrance vestibule is visible in this picture, showing coves.

For the bank officers' area (below right) custom made chandeliers consist of five single fixtures suspended from the ceiling, and brought into an integral unit by means of a black walnut ring. The drop of each fixture varies six inches to produce a carillon effect. All metal parts of the luminaire are in dull brass, walnut ring has edge in cerulian blue. Note dropped perimeter lighting on the left wall. This is part of the total scheme to produce peripheral wall effect throughout the bank. High-hat units (visible at right in picture) are across the front and return side of the vestibule to highlight the front planters.

American Standard Practice For Protective Lighting

Prepared by Sectional Committee A85 of the American Standards Association; sponsored by the Illuminating Engineering Society.

FOREWORD

(This foreword is not a part of the "American Standard Practice for Protective Lighting")

During World War II, at the request of the War Department and the Insurance Committee for the Protection of American Industrial Plants, the American Standards Association initiated a project on outdoor protective lighting of industrial properties for the purpose of averting theft and sabotage. The ASA War Standards Procedure was applied and a War Standards Committee prepared and published the American Standard, A85-1942, "Protective Lighting for Industrial Properties."

In 1948 the ASA Safety Code Correlating Committee decided to terminate the War Standard and institute a revision for current use. The Illuminating Engineering Society was designated administrative sponsor. The I.E.S. Protective Lighting Committee developed the first draft of this revision which the Sectional Committee used as a basis for this American Standard Practice.

This standard is intended as a guide for outdoor protective lighting to those whose responsibility it is to provide for plant protection. The standard sets forth the principles involved, the points to be lighted, and the minimum degree of illumination considered necessary for the detection of persons bent on theft and trespassing. In the appendix suggestions are given for obtaining the performance prescribed in the specifications.

It is not intended that this Standard should be considered for use in preventing accidents to regular employees of industrial plants engaged in their normal industrial pursuits. For lighting information of this character the user is referred to the "American Standard Practice for Industrial Lighting," A11.1-1952 approved by the American Standards Association.

Sectional Committee A85 is composed of representatives officially designated by the participating societies and organizations. Sponsor of this Standard is the Illuminating Engineering Society.

The principles set forth herein are applicable to other areas as well as industrial properties

1. Purpose

The purpose of this American Standard is to set up general rules supplemented by appendix material which will be sufficiently comprehensive for adaptation to specific situations.

"Protective" lighting is an auxiliary to "productive" lighting, and it may also reduce fire risk. The illumination levels recommended are believed necessary for night-time policing of outdoor areas by discouraging would-be intruders and rendering them visible to plant guards should they attempt entry. However, illumination for policing is not usually adequate for efficient plant operations. For example, the lighting recommended as a protective measure for a stock pile is unlikely to permit the maximum efficiency and safety for workmen handling the material. Industrial plants differ widely in their physical character and thus no attempt is made to state specific rules applicable to all possible conditions.

2. Definitions

The following terms are defined for the purpose of this Standard. For more complete definitions refer to "Illuminating Engineering Nomenclature and Photometric Standards," prepared under the leadership of the Illuminating Engineering Society and approved as American Standard (Z7.1-1942) by the American Standards Association, and on which the definitions in this Standard are based.

2.1—*Candlepower* — Candlepower is the luminous intensity expressed in candles.

2.2—*Footcandle* — The footcandle is the illumination produced at a surface all points of which are at a distance of one foot from a uniform point source of one candle.

2.3—*Horizontal Illumination* — Horizontal illumination is the illumination expressed in footcandles on a horizontal surface. For the purposes of this Standard, the surface is considered at ground level.

2.4—*Lumen* — The lumen is the unit of luminous flux, and as applied to lamp ratings indicates the light output.

2.5—*Vertical Illumination* — Vertical illumination is the illumination expressed in footcandles on a vertical surface.

2.6—*Variation Range* — Variation range of illumination on a given plane is the ratio of the maximum illumination to the minimum illumination on that plane.

3. Principles of Protective Lighting

(a) Good protective seeing is achieved by adequate light upon bordering areas, glaring light in the eyes of the trespasser, and no light on the guard. In aiming to provide protective seeing, high brightness contrast between trespasser and background should be a first consideration. This may be accomplished by adequate light and proper use of paint and ground cover materials.

(b) Two basic systems or a combination of both may be used to provide practical and effective protective light-

ing. The first method is to light the boundaries and approaches; the second, to light the area and structures within the general boundaries of the property.

(c) To be effective, protective lighting should:

(1) Discourage or deter attempts at entry by intruders. Proper illumination may lead a potential intruder to believe detection inevitable. However, lighting should not be used alone. It should be employed with other measures such as fixed or patrolling guards, fences, alarms, etc.

(2) Make detection certain should entry be effected.

(3) Avoid glare that handicaps the guards and annoys street and highway traffic, marine or railroad operations, workers on neighboring projects, or occupants of adjacent buildings. Glare directed at the intruder, if not in violation of the above, is effective in handicapping the intruder and preventing the discovery of the guard.

(4) Provide complete reliability. Failure of a single lamp should not leave a dark spot vulnerable to entry.

(5) Provide special treatment for such situations as railroad sidings, alleys, roofs of abutting buildings, wooded or water approaches, entrances and exits.

(6) Provide adequate illumination. The amount of light required depends upon the accessibility and vulnerability of the property.

(7) Provide convenient control and maintenance. Controls for blackout purposes may be necessary.

(8) Provide supplementary searchlights controllable by the guards to permit exploration outside of property, or to augment fixed lighting systems for emergencies.

(9) Provide for poles, lighting equipment, and electrical auxiliaries to be located inside the property fence, or where they are not readily accessible to malicious damage.

(d) All references to footcandles in this Standard refer to the minimum horizontal illumination at ground level except where otherwise stated. These are minimum values and special consideration may be necessary to compensate for color of surroundings and adverse atmospheric conditions. Painting surfaces a light tint is helpful

TABLE I — Boundary Lighting Standards.

Item	Plant Classification	Width of Lighted Strip: Inside Boundary Feet	Width of Lighted Strip: Outside Boundary Feet	Illumination: Minimum At any Point on Ground Footcandles	Within Lighted Strip: Maximum Permissible Variation Range: Along Boundary Line	Within Lighted Strip: Maximum Permissible Variation Range: Throughout Lighted Strip
A	Critical	25	200*	0.15*	....	10:1
	Average	25	200*	0.07*	....	20:1
B	Critical	10	70	0.04	6:1	25:1
	Average	10	70	0.02	10:1	40:1
C	Critical	20	40	0.08	6:1	15:1
	Average	20	40	0.04	10:1	30:1
D	Critical	30**	30**	0.10	6:1	19:1
	Average	30**	30**	0.05	10:1	25:1
E	Critical	50 feet total width from building face		0.10	6:1	15:1
	Average			0.05	10:1	30:1
F	Average	80 feet total width from building face		0.04	10:1	30:1
G	Critical	10	50	0.10	8:1	20:1
	Average	10	50	0.05	8:1	20:1
H	....	25	25	2.0	....	5:1
J	....	50	50	1.0	....	10:1

*Footcandle values and ratios listed opposite Item A are on *vertical* plane 3 feet above ground and parallel to fence. In addition to the listed requirements, there shall be sufficient illumination on the ground from 10 feet inside to 25 feet outside the fence to assure ready detection of persons. The application is of the "Glare Projection" type and is suitable only where there are no adjacent roads, railroads, navigable water or other properties which may suffer a glare hazard.
**The width of lighted strip may be reduced to 20 feet inside and 20 feet outside the fence in cases where the property to be protected is less than 10,000 square feet in total area.

many times in correcting otherwise dark recesses. There should be planning for the most adverse conditions. The application of the above principles to the design of a specific protective lighting system cannot be covered in this standard and must be left in the hands of the technical personnel of industry.

4. Lighting Specifications

4.1—*Boundaries and Approaches*

4.1.1—The illumination of boundaries (fenced, unfenced, building face, water front) and entrances shall be in accordance with the following text and the provisions of Table I.

4.1.2—*Boundaries* — Boundaries consist of the property lines unless a fence is erected within the property line, in which case the fence shall be taken as the boundary.

4.1.3—*Fenced Boundaries* — Fenced boundaries shall be classified as follows:

(a) *Isolated fenced boundaries* consist of fence lines around large isolated plants where the fence is 100 feet or more from buildings and operating areas, and where the approach area is clear of obstruction for 100 or more feet outside the fence. In general, two types of lighting are acceptable for these boundaries, and the standards for these are indicated in Table I, items A and B. Item A covers so-called "Glare Projection" systems by means of which high intensity horizontal beams are projected toward a would-be intruder to produce glare in his eyes and make him readily visible to a guard. This type of lighting is not permissible where there are railroads, roads, navigable water, or adjacent property within 200 feet of the lighting units or otherwise located so they will suffer a glare hazard. Item B covers lighting systems other than the "Glare Projection" types, and systems meeting iltem B standards are applicable to any isolated fenced boundary. In all cases the patrol roads and paths shall be kept unlighted.

(b) *Semi-isolated fenced boundaries* consist of fence lines where approach areas are clear of obstruction for 60 to 100 feet outside the fence. The lighting system for this type of boundary shall conform to the standards of Table I, item B. Patrol roads and paths shall be kept in relative darkness.

(c) *Non-isolated fenced boundaries* consist of fence lines where the property to be protected is immediately adjacent to operating areas of other plants or to public thoroughfares, where outsiders may move about freely in approach areas (close to fence). In such cases the standards of Table I, items C or D shall apply depending on the relative clear width inside and outside the fence. It may not then be practical to keep the patrol area dark.

4.1.4—*Building Face Boundaries* — Building face boundaries consist of the

faces of buildings which are on or within 20 feet of the property line and where the public may approach the buildings. In such cases fences may or may not be provided and the guards may be stationed inside or outside of the building. Doorways or other insets in the building face shall receive special attention to eliminate shadows. The lighting system shall conform to the standards in Table I, item E.

4.1.5—*Unfenced Boundaries* — Unfenced boundaries consist of property lines located more than 20 feet from buildings, with no fence provided, and with no outdoor operating areas between buildings and property lines. In such cases, since no other barrier exists, the light barriers shall extend at least 80 feet outward from the building on the unobstructed area. The lighting system shall conform with the standards in Table I, item F. Doorways or other insets in the building face shall receive special attention to eliminate shadows.

4.1.6—*Waterfront Boundaries* — Waterfront boundaries consist of property lines, fenced or unfenced, at or adjacent to bodies of water. The standards of Table I, item G, shall apply, except that in the case of non-navigable water of less than 15 feet in width they shall be clasified under the provisions of 4.1.3 to 4.1.5 inclusive and handled as though the body of water were not present. In any case, there shall be no concealing shadow areas on or near the water close to the sea wall or bank. The U.S. Coast Guard shall be consulted for approval of the proposed protective lighting adjacent to navigable waters. (For lighting of docks and piers, see 4.2.4)

4.1.7—*Entrances* — Entrances may be gates, doors, or passages through the boundaries, authorized for constant or occasional use at night. Active (constantly lighted and attended) pedestrian and conveyance entrances shall be provided with two or more luminaires and with adequate illumination for recognition of persons and examination of credentials. All conveyance entrances shall have two luminaires so located as to facilitate complete inspection of passenger cars, trucks, freight cars, etc., their contents and the space underneath such equipment. Pedestrian entrance lighting shall conform with the standards of Table I, item H, and conveyance entrance lighting shall conform with the standards of Table I, item J. Inactive entrances (normally locked and infrequently used at night) may be equipped with auxiliary switching, and lighted as such only when in use.

4.2—*Areas and Structures Within Property Lines*

4.2.1—The areas within the property line consist of industrial thoroughfares, yards, storage spaces, unoccupied and large working areas, piers and docks, and vital structures, among which buildings under construction may be part.

4.2.2—The illumination of industrial thoroughfares shall be as follows:

(a) The illumination of thoroughfares not bordered by buildings shall be not less than 0.50 footcandle at any point.

The avenues over which heavy trucking and main industrial movements take place may be lighted by means of suspension luminaires or floodlights, depending upon the problems involved. (Main trucking roads away from buildings may be illuminated in a manner illustrated in Figures 11a and 11b of the Appendix C. Roads forming a part of an open area may also be treated satisfactorily as recommended in 4.2.3 under yards.)

(b) The illumination of thoroughfares bordered by buildings on both sides or along one side shall be not less than 0.20 footcandle at any point. (Figures 11a and 11b of the Appendix C, p. 186 suggest typical layouts which may be used as a guide.)

4.2.3—The illumination of open yards (defined to consist of unoccupied land only) and of outdoor storage spaces (defined to include material storage areas, railroad sidings, and parking areas) shall be as follows:

(a) The illumination of outdoor storage spaces shall be not less than 0.10 footcandle at any point. The lighting units shall be placed so as to provide an adequate distribution of light in aisles, passageways, and recesses, to eliminate shadowed areas where unauthorized persons may conceal themselves. (See Appendix C-2.4)

(b) The illumination of open yards consisting of areas adjacent to boundary limits (between guards and fences) shall be in accordance with the provisions of 4.1-Boundaries and Approaches. The illumination of all open yards within the boundaries, except as described in the foregoing sentence, shall be not less than 0.02 footcandle at any point. All remaining areas may be left dark unless conditions peculiar to a particular plant or enterprise make lighting necessary. Where lighting is deemed necessary, the illumination shall be not less than 0.02 footcandle at any point. (See Appendix C-2.3)

4.2.4—Piers and docks that form part ofan industrial property shall be safeguarded by illuminating both the water and land approaches in accordance with the following table:

Decks of open piers	0.10 ft-c
Land approaches	(See 4.2.2 and 4.2.3)
Sub-structures	(See Appendix C-2.5)
Water approaches (extending to distance of 100 feet from pier)	0.05 ft-c

The land approaches to an industrial pier are, in general, avenues or open areas and the lighting facilities shall conform to those stated in 4.2.2 and 4.2.3.

Supplementary lighting (see Appendix C-3) capable of being directed as required by the guards is recommended as a part of the protective lighting system for piers and docks.

The lighting shall not in any way violate marine rules and regulations nor be glaring to pilots. The U.S. Coast Guard shall be consulted for approval of the proposed protective lighting adjacent to navigable waters.

4.2.5—The illumination of vital structures and buildings under construction shall be as outlined in the following paragraphs:

(a) The vertical surfaces of all vital structures most easily and seriously harmed at close range shall be lighted to a minimum height of eight feet. These surfaces and the areas immediately surrounding such structures shall be lighted to not less than 2 footcandles. (Appendix C-2.6 contains suggestions for lighting those vital structures that fall in this category.)

(b) Vital structures that may be easily harmed from a distance with serious effects on production shall not be lighted, thereby lessening their visibility to saboteurs.

(c) The protective illumination of areas occupied by construction projects shall be not less than 0.02 footcandle at any point.

Appendix A — Lighting Equipment

(This appendix is not a part of the American Standard Practice for Protective Lighting. It includes a discussion of the specifications and recommendations for ways and means of putting the specifications into effect.)

A-1—*General* — A wide range of lighting equipment is available, most of which finds some application around a plant but none of which is universally adaptable for all purposes. Broadly speaking, there are four general forms of lighting units in use for protective lighting systems. These four classifications are: (1) floodlights, (2) street lights, (3) Fresnel lens luminaires, and (4) searchlights. In choosing the type best suited for the purpose at hand consideration must be given to the pattern of light distribution; the tendency to cause objectionable glare under normal conditions; the mechanical construction and convenience of servicing; and the overall suitability of the unit for the application at hand. A brief description is given of the four types of lighting units referred to. (See Table A-I, p. 178.)

A-2—*Floodlights* — Floodlights are designed to form the light flux generated by a lamp into a beam for the purpose of projecting it to distant points or for emphasizing definite areas. A floodlight is specified in wattage and beam width; the latter, expressed in degrees, defines the angle included by the beam. A common method of roughly classifying beam widths is by the terms *narrow*, *medium*, and *wide* as indicated in Table A-I (p. 178). Floodlights are in general restricted to multiple circuits as they are not insulated for high potential series circuits. They may be open or enclosed, the latter being equipped with a cover or door glass to exclude rain and dust. The enclosed floodlight is to be preferred in most instances to protect the lamp against damage from rain and also the reflecting surfaces and lamp from the deteriorating effect of exposure to the atmosphere.

The beam width required will depend upon the area to be covered, the angle at which the beam strikes this area and the distance of the floodlight from the area. Beam width is determined by the contour and finish of the reflector and the type of lamp used, and may be further modified by the type of door glass with which it is equipped.

Floodlights may be obtained in a great variety of beam characteristics and for many types and sizes of lamps. Considerable skill is required in correctly applying the floodlight to insure adequate coverage of the area to be lighted and to avoid glare as referred to in 3(b)(3) of this Standard Practice. It may be successfully used for the illumination of boundaries, fences, areas, buildings, and for local emphasis of vital areas or buildings.

Reflectorized lamps with suitable holders are also used for floodlighting. These lamps have a bulb of suitable contour on part of which vaporized metal is internally deposited to form a reflector. Two variations are designated as reflector lamps, which have blown glass bulbs (both indoor and outdoor types) and projector lamps which have accurately molded, mechanically strong, heat-resistant glass bulbs with sealed on cover glasses.

Reflectorized lamps are applicable for lighting irregular spaces such as around tanks, building setbacks, piles of material and for local lighting around vital locations, doorways, narrow spaces between buildings and boxcars, and for boundary lighting especially where the light must be confined to the immediate fence area.

A-3—*Street Lights* — Street lights are rated by the size of lamp accommodated and the characteristics of the light distribution. Luminaires in this classification may be operated from series or multiple circuits (see Appendix B) and it is common practice to use up to 10,000-lumen lamps in series luminaires and up to 500-watt lamps in multiple luminaires.

The distribution of light may be symmetrical or asymmetrical. A symmetrical distribution is one in which the distribution of light and candlepower value are approximately the same in any vertical plane (Street Light, Type V and reflector, symmetric, Table A-I) passing through the axis of the luminaire. Such a distribution of light finds application in lighting large areas where the luminaires may be located centrally with respect to the area to be lighted; also at entrances, exits, and for special boundary conditions.

The asymmetrical distribution (Street Light, Types I, II, III, and IV, Table A-I) may take one of many forms and has for its purpose a higher utilization of the light by directing it by reflection, refraction, or both, into useful directions. The asymmetrical distribution finds application at situations where the position of the lighting unit is restricted as to location with respect to the area lighted, under which conditions the symmetrical distribution would be wasteful or ineffective. An example of the use of the asymmetric distribution is for boundaries where it is advisable to locate the lighting unit inside the property and deliver the light largely outside the fence; also for roadways where the pole of necessity must be placed outside the limits of the roadway but the effective light is that reaching the road surface.

A-4—*Fresnel Units* — The Fresnel lens luminaire, used for protective lighting, delivers a fan-shaped beam of light approximately 180 degrees in the horizontal and from 15 to 30 degrees in the vertical (Table A-I). It is intended to afford protection to a property by directing the light outward to illuminate the approaches and inflict glare on the would-be intruder while affording the guard comparative concealment in darkness. The 300-watt multiple lamp or 6000-lumen series lamp is commonly used with this unit. Its application is limited to locations where advantage may be taken of its unique characteristics without causing objectionable glare to neighboring activities.

A-5—*Searchlights* — Where searchlights are empolyed in protective lighting systems they are usually of the incandescent type because of the small amount of attention required for their operation and because of their simplicity and dependability. Searchlights are rated in diameter of reflector and lamp wattage, and for applications referred to herein fall within the range of 12 to 24 inches and 250 to 3000 watts. The beam angles of these searchlights range between 3 and 8 degrees. (Table A-I.)

The general types of mounting in use are the pilot house control type and the trunnion and pedestal types. The pilot house control type finds application on top of guard houses and places the control of the searchlight in the hands of the guard inside the house (Fig. 15, p. 188) to permit exploration of areas within or without the property or to supplement, when and where required, the fixed lighting within the property. The trunnion and pedestal types may be directed at will by the guard, or used with a fixed setting to illuminate local areas.

The general application of searchlights is to supplement the fixed lighting at the plant; size and wattage will depend upon local requirements.

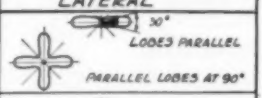
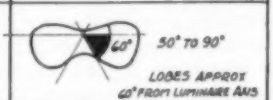
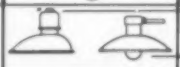
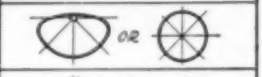
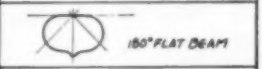
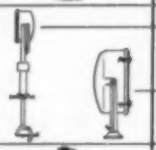
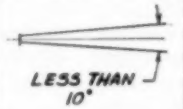
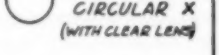
A-6—*Light Sources*

A-6.1—*Standard Filament Lamps*

(a) Because of their simplicity, dependability and range of sizes, filament lamps are the most commonly used light sources for protective lighting. They may be operated on either direct or alternating current.

(b) General service lamps are used in floodlights and many types of interior luminaires. The most widely used sizes are listed below with data taken from the *IES Lighting Handbook*. These values should be checked from time to time

TABLE A-I — Typical Equipment for Protective Lighting.

LUMINAIRE		TYPE	PHOTOMETRIC DESIGNATION	OPEN OR ENCLOSED	TYPICAL DISTRIBUTION CHARACTERISTICS	
					VERTICAL	LATERAL
STREETLIGHT		I	TWO-WAY FOUR-WAY	ENCLOSED		
STREETLIGHT		II	NARROW ASYMMETRIC FOUR-WAY	ENCLOSED		
STREETLIGHT		III	MEDIUM WIDE ASYMMETRIC	ENCLOSED		
STREETLIGHT		IV	WIDE ASYMMETRIC	ENCLOSED		
STREETLIGHT		V	SYMMETRIC	ENCLOSED		
REFLECTOR			ASYMMETRIC OR SYMMETRIC	OPEN		
FRESNEL LENS		GLARE PROJECTION	ASYMMETRIC	ENCLOSED		
SEARCHLIGHT			EXTREMELY NARROW BEAM	ENCLOSED		
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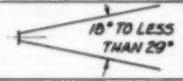
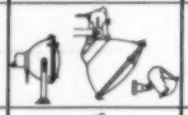
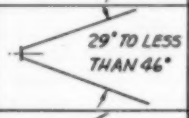
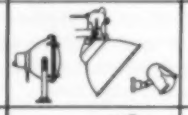
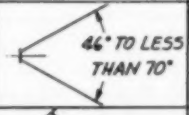
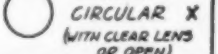
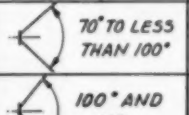
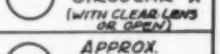
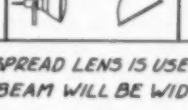
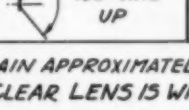
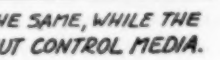
FLOODLIGHT		2	NARROW BEAM	ENCLOSED		
FLOODLIGHT		3	MEDIUM BEAM	ENCLOSED		
FLOODLIGHT		4	MEDIUM WIDE BEAM	ENCLOSED OR OPEN		
FLOODLIGHT		5	WIDE BEAM	ENCLOSED OR OPEN		
FLOODLIGHT		6	VERY WIDE BEAM	ENCLOSED OR OPEN		

X NOTE: IF A SPREAD LENS IS USED THE VERTICAL SPREAD WILL REMAIN APPROXIMATELY THE SAME, WHILE THE HORIZONTAL BEAM WILL BE WIDENED CONSIDERABLY. ◯ A CLEAR LENS IS WITHOUT CONTROL MEDIA.

STREET LIGHTING LUMINAIRES ARE TYPICAL ACCORDING TO ASA DESIGNATION.

FLOOD LIGHTING LUMINAIRES ARE TYPICAL ACCORDING TO NEMA AND IES DESIGNATION.

REFLECTORIZED LAMPS FALL INTO FLOODLIGHT CLASSIFICATIONS ACCORDING TO THEIR DISTRIBUTION CHARACTERISTICS

with the latest edition of the handbook or with the manufacturer.

(c) Streetlighting lamps are specially designed to meet the peculiar demands of this service. They are also used in Fresnel luminaires. Series types are listed in the table under "Street Series Lamps." Their life rating is 2000 hours. A companion line of lamps for multiple operation with equivalent lumen ratings is also available. In both series and multiple types there are companion lines rated at 3000 hours for installations where lamps are group replaced.

(d) Searchlights are equipped with either general service lamps, floodlamps or spotlamps. The most widely used floodlamps and spotlamps are listed.

A-6.2—***Reflectorized Lamps*** — Uses are outlined in Paragraph 4.1 under Floodlight Equipment. All types are rated at 2000 hours life.

A-6.3—***Vapor Lamps*** — Lamps in which light is produced directly or indirectly by the action of a mercury or other gases require a current limiting device for stable operation. Standard practice is to use a reactor in series with the lamp. Mercury lamps require a warm-up period and in the event of a momentary power interruption when the lamp is hot, it will not relight for a period of about five minutes or more. This limits the use of such sources in protective lighting; however, their high efficiency and economy on high voltage circuits merits consideration in some situations. Mercury lamps are made in several sizes; the most widely used being 400 watts. Sodium lamps are used in special streetlights. Their efficiency in producing light is high, but their distinctive yellow color and warm-up time limits their use for protective lighting.

Appendix B — Electrical Distribution and Control

(This appendix is not a part of the American Standard Practice for Protective Lighting.)

B-1—***Types of Circuits*** — Electrical distribution circuits for protective lighting may be either the multiple or series type. (See Figs. 1-4.) In the case of multiple circuits the lamps used are rated at a specified voltage and are connected in parallel with each other across the lines. The principal advantage of multiple lighting is that it uses the same kind of lamps and other associated equipment as are normally used for building lighting and with which plant electrical and maintenance men are already familiar. It is applicable to every kind of luminaire mentioned in this standard including street lighting luminaires.

General Service Lamps

Watts	Bulb	Base	Approx. Initial Lumen Output	Rated Life (Hours)
100	A21	Medium screw	1630	750
200	PS30	Medium screw	3700	750
300	PS35	Mogul screw	5650	1000
500	PS40	Mogul screw	9900	1000
750	PS52	Mogul screw	15600	1000
1000	PS52	Mogul screw	21500	1000
1500	PS52	Mogul screw	33000	1000

Street Series Lamps

Rated Initial Lumens	Current Ratings (Amperes)	Bulb Size	Base
4000	6.6 or 15	PS35	Mogul screw
6000	6.6 or 20	PS40	Mogul screw
10000	6.6 or 20	PS40	Mogul screw
15000	20	PS40	Mogul screw

Floodlamps and Spotlamps for Use in Searchlights

	Watts	Bulbs	Rated Life (Hours)	Filament	Approx. Initial Lumens*	Base
Floodlamps	1000	G40	800	C5	19500	Mogul screw
	1500	G48	800	C5	30000	Mogul screw
Spotlamps	1000	G40	200	C5	22500	Mogul screw
	2000	G48	200	C13	52000	Mogul bipost

*In an 80° cone.

Projector and Reflector Lamps

	Type	Watts	Bulb	Base	Beam Spread
Reflector Lamps					
Indoor	Spot	150	R40	Md. Sc.	30°
	Flood	150	R40	Md. Sc.	60°
May be satisfactory outdoors if protected from rain.	Spot	300	R40	Md. Sc.	30°
	Flood	300	R40	Md. Sc.	60°
		500	R52	Mg. Sc.	110°
		550	R52	Mg. Sc.	110°
		550	R57	Mg. Sc.	....
		750	R52	Mg. Sc.	110°
		800	R52	Mg. Sc.	110°
		800	R57	Mg. Sc.	....
		1000	R52	Mg. Sc.	110°
		1000	RB52	Mg. Sc.	135°
Outdoor	Spot	300	R40	Mg. or Md.	30°
	Flood	300	R40	Mg. or Md.	60°
Projector Lamps	Spot	150	PAR38	Md. Sc.	30°
	Flood	150	PAR38	Md. Sc.	60°
	Spot	150	PAR38	Md. Side Prong	30°
		150	PAR38	Md. Side Prong	60°
		200	PAR46	Md. Side Prong	20 x 40°
	Spot	200	PAR46	Md. Side Prong	17 x 23°
	Narrow Spot	300	PAR56	Mg. End Prong	15 x 20°
	Med. Flood	300	PAR56	Mg. End Prong	20 x 35°
	Flood	300	PAR56	Mg. End Prong	30 x 60°
	Narrow Spot	500	PAR64	Mg. End Prong	13 x 20°
	Med. Flood	500	PAR64	Mg. End Prong	20 x 35°
	Flood	500	PAR64	Mg. End Prong	35 x 65°

In the case of series circuits the lamps used are of the constant-current type and are connected in series with each other along a single wire loop circuit. Series lighting is especially adaptable to boundary lighting using street lighting types of luminaires and where considerable distances along the boundaries need to be lighted. The series system permits a saving in conductors over the multiple system for long circuits. Constant-current transformers are required to supply series circuits.

B-2—***Control Methods***—Normal control of a lighting system may be either manual or automatic and should be independent of the interior lighting system. Where personnel is available and can be assigned to do so, turning the lights off and on manually is the simplest and cheapest method. In some cases, however, it may be desirable to control the lights automatically. For this purpose there are available time switches, with or without automatic seasonable time correction (astronomic dials), and photo-

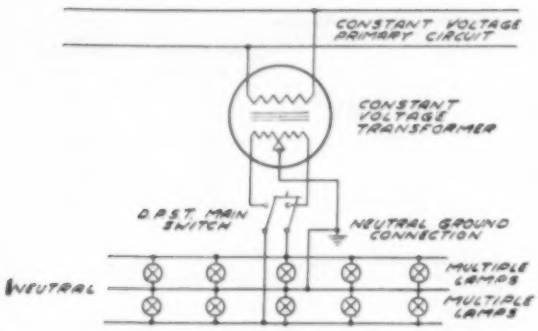


Figure 1. Simplified diagram of direct control for a multiple lighting circuit.

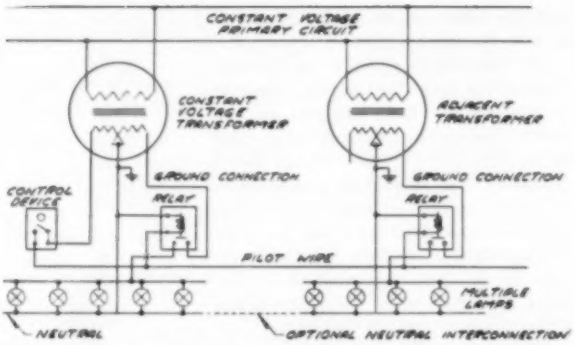


Figure 2. Simplified diagram of remote control for a multiple lighting circuit.

electric controls which operate as a result of the change in amount of light at dawn and dark. If an automatic control is provided for normal operation, a manually operated switch should also be provided to turn off the lights promptly in case of blackouts.

Both manual and automatic schemes are adaptable to remote control of the actual lighting circuits by means of relays operated by pilot wire circuits, polarized impulses, or carrier current. Remote control from a single centralized point tends toward inflexibility in normal operation but has the advantage of simplicity for cutting off all lights quickly in case of a blackout.

B-3—*Multiple Systems* — A typical diagram of a simple multiple system fed from a single constant-voltage transformer is shown in Fig. 1 (above). The lights are controlled by a manually operated double-pole single throw switch and the lamps are connected to both sides of the 3-wire secondary circuit. Instead of the control switch in the secondary, the primary circuit could be arranged to supply only transformers serving protective lighting, in which case the primary circuit could be controlled by means of a high-voltage switch.

A typical diagram of one form of remote-control multiple lighting circuit is shown in Fig. 2. The diagram shows the lighting circuits in more than one section, each fed by a separate transformer, but controlled by a single-control device by means of a pilot wire which actuates a relay for each section. The relays shown are single pole but double-pole relays are available so that 3-wire instead of 2-wire lighting circuits may be controlled. Where the pilot wire method is used the relay switch could be of the normally closed type, instead of the normally open type shown, but with the disadvantage of having the lights come on during a blackout if the pilot wire becomes broken. Instead of the pilot wire method, the cascade method can be used in which each relay has its operating coil connected in multiple with the lamps of the preceding lamp section. Only normally open relays may be used for such service. A series-multiple relay may be used in place of the control device shown to control a multiple system in cascade

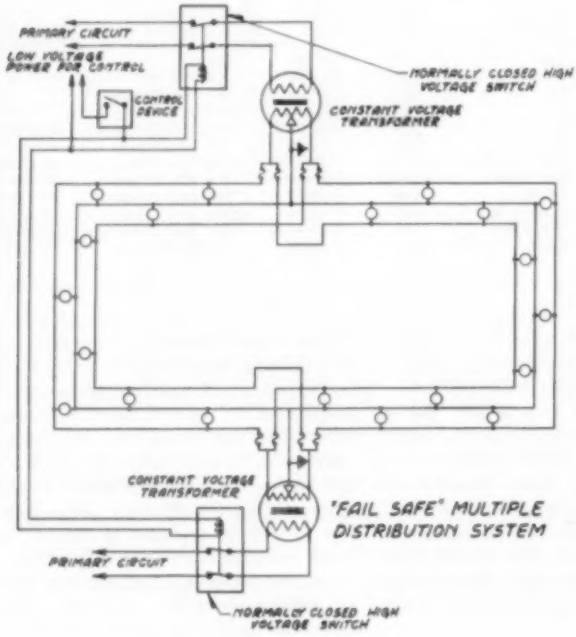
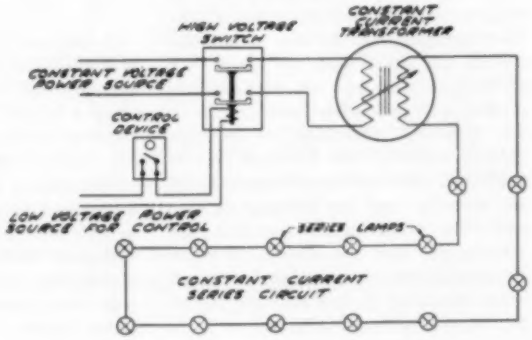


Figure 3. (left) Simplified diagram for a "fail safe" multiple distribution system of control for a multiple loop or banked secondary system. Control circuit must be energized to turn light off.

Figure 4. (below) Simplified diagram of control for a series lighting circuit.



with a series system. Consideration should be given to a loop system wherever feasible.

A typical diagram for a loop or banked secondary circuit is shown in Fig. 3. This circuit may utilize as many transformers as desired and due to its loop characteristics the circuit must be broken in two places in each leg before any lamps are extinguished. Short circuiting one leg will render the light inoperative in that leg only. A "fail-safe" system of pilot wire control with normally closed switches, so that the control circuit must be energized in order to turn the light off, is desirable since any damage to the control circuit will turn the lights on. Such a control circuit can be used with most multiple or series systems except those using a cascade system.

B-4—*Series Systems* — A typical diagram of a series lighting system and control is shown in Fig. 4. The high voltage switch used to energize the constant-current transformer is shown as remotely controlled by a separate control device which opens and closes a low-voltage circuit through the operating coil of the high-voltage switch. Such high-voltage switches are also available with an integral control devices such as a time switch. Instead of the control device shown, another series circuit, which is itself properly controlled, may be cascaded through the operating coil of the high-voltage switch if the operating coil is designed for such service. In this case the operating coil of the high-voltage switch is placed in series with the lamps of the other series circuit. Instead of the remote control methods discussed above the high-voltage switch may be manually operated.

B-5—*Duplicate Circuits and Supply* — In order to improve reliability of service it is possible to provide two or more circuits so that every other light may be served from different circuits. This is applicable to both series and multiple circuits. In view of the extra amount of material required and the complexity of the system, especially in the case of multiple systems, such provisions may need consideration only for critical situations. It is also possible to provide automatic throw-over switches to transfer the lighting system from the normal source of power to a duplicate source or an auxiliary source in case of failure of the usual source of supply. Auxiliary sources of power may be storage batteries or generators driven by any of the usual types of prime movers. It should be pointed out that direct-current auxiliary sources are not adaptable to serving series lighting systems or multiple lighting systems using control devices which are designed for alternating current operation.

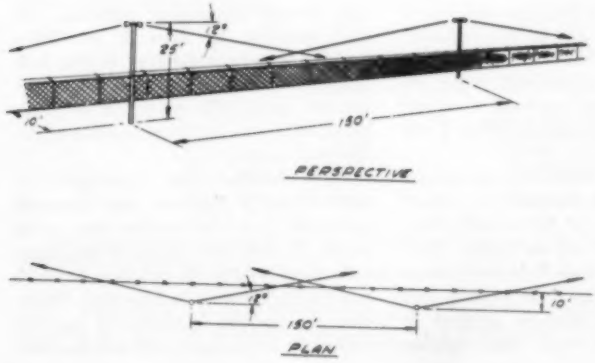
B-6—*Construction* — Construction of lighting circuits and supports should be in accordance with good modern practice and in accordance with recognized codes covering construction and operation. The codes to which reference should be made and which have been approved as American Standard by the American Standards Association are the National Electrical Code and the National Electrical Safety Code, or the latest revisions of these as approved by the American Standards Association.

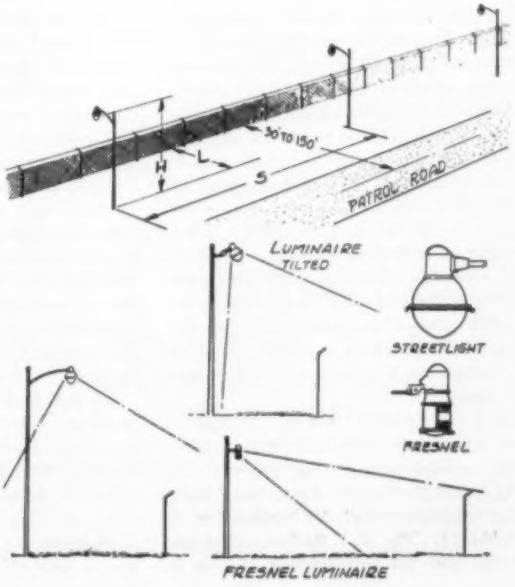
B-7—*Voltage* — The light output of incandescent lamps is a function of the voltage supplied. As a general rule, lamps should be operated at rated voltage. Undervoltage operation of as little as 5 per cent below normal results in a loss of light amounting to 16 per cent. The light output of vapor lamps is affected to this extent by line voltage since the ballast design may provide for inherent compensation or compensation by means of different line taps. In the design of the electrical distribution for protective lighting the voltage drop is an important factor and the maximum permissible drop should be governed both by the economics of line loss and the reduction of light output due to voltage drop.

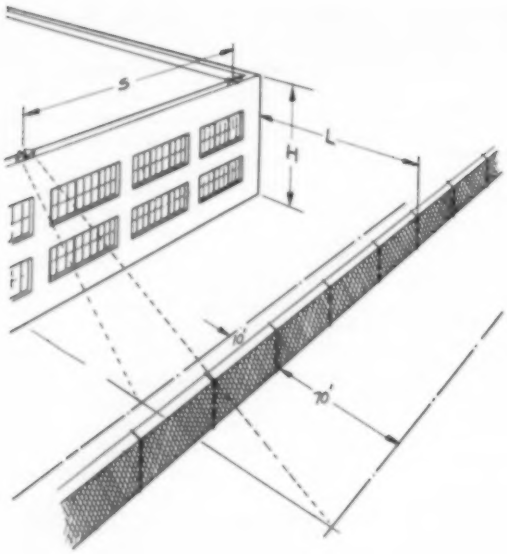
B-8—*Maintenance* — The light output from any lamp and luminaire combination will decrease as it is operated. Lumen output of constant voltage incandescent lamps decreases throughout life due to bulb blackening and filament evaporation. The lumen output of series incandescent lamps remains nearly constant throughout life. The light output from any luminaire decreases as dirt collects on reflector and glassware surfaces. Periodic cleaning of lighting equipment is essential to maintain recommended footcandle levels. Inoperative luminaires in a protective lighting system cannot be tolerated since they leave an unlighted hole in the wall of light around the area. The necessity of frequent trips to replace individual lamp burnouts can be greatly

Figure 5a. (below) Boundary lighting with PAR-46 floodlamps.

Figure 5b. (right) Isolated fenced boundaries using street or Fresnel type luminaires.







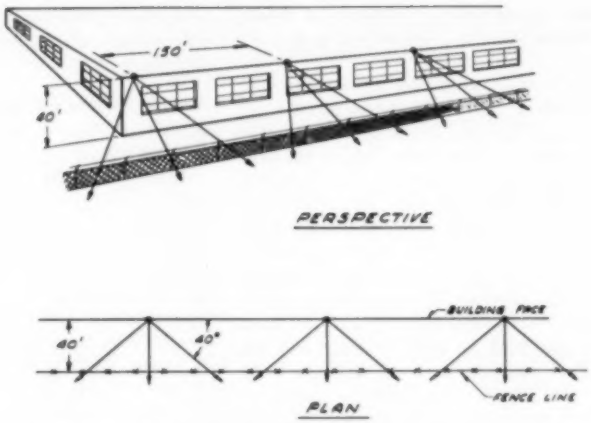


Figure 6a. (left) Non-isolated fenced boundaries using floodlights.

Figure 6b. (above) Non-isolated fenced boundary lighting from building parapet with 150-watt PAR-39 floodlamps.

reduced by adoption of a systematic group replacement program. Lamps should be group replaced at 70-80 per cent of normal rated life which should reduce the number of random replacements between group replacements to about 15 per cent of the total installation.

Appendix C.—Typical Methods of Obtaining Specified Illumination Values

(*This Appendix is not a part of the American Standard Practice for Protective Lighting.*)

C-1—*Boundaries and Approaches* — Typical suggested methods designed to meet the specifications of Section 4 are described herein. Other installations which will meet the specifications are acceptable. (Figs. 5a & 5b.) For example, longer spacings and higher mounting heights of luminaires using larger lamps may be designed to meet the specifications, and where practical these may be more economical. Fenced boundaries are assumed to utilize wire mesh fences and these should be dark in color. Where strand or barbed wire fences of little or no screening effect are used, still other types of lighting may be practically designed to meet the specifications of Section 4. Experienced engineers should be consulted for design or approval of such systems.

C-1.1 — *Isolated Fenced Boundaries* which are sufficiently remote from adjacent working areas, roads, etc. to permit the use of the "Glare Projection" lighting system covered by application A, Table C-I. (Fig. 5b.) Such a system conforms with the specifications of item A, Table I. Though limited in application, this system has several advantages. A patrol road or path 30 feet or more back of the pole line will remain in practically total darkness, which in combination with the glare projected outside the property makes it virtually impossible for would-be intruders to see into the property. Intruders up to 250 or 300 feet from the fence are visible to the guards. Mounting the units approximately one foot from the poles with short adjustable brackets and at low mounting heights is permissible. Care should be taken in properly aiming and leveling the units to avoid excessive lighting of the top of the inner face of the fence. Precautions listed under 4.1.3 (a) should be carefully noted.

Another satisfactory method for lighting isolated fenced boundaries is application B, Table C-I, discussed below. This application conforms with the specifications of item B, Table I.

C-1.2—*Semi-Isolated Fenced Boundaries* lend themselves readily to application B, Table C-I. Patrol roads or paths 50 feet or more back of the pole lines will remain in comparative darkness, and would-be intruders up to 150 to 200 feet outside the fence are visible to the guards. No objectionable glare will result on property outside the approach area and the specifications of item B, Table I will be met.

As indicated in Table C-I application B (Fig. 5b), it is necessary to mount some combinations of lamps and street lighting luminaires at an angle, tilted outward. In such cases it is desirable to use a bracket designed to permit such adjustment rather than to attempt to use a conventional rigid street lighting bracket. Care in adjustment is required in order to meet the requirements.

C-1.3—*Non-Isolated Fenced Boundaries* differ from the above two cases in that the width of the lighted area inside the plant property is increased and the width of the lighted area outside the plant property is decreased. (Fig. 6a) In addition since adjacent property outside the plant is most likely to be a highway, railroad right of way, residential property or the operating section of another industrial plant, it is necessary to control the glare from the lighting installation. Due to the nature of adjacent property strangers may be authorized to move about close outside the fence, requiring adequate lighting for recognition of persons.

Methods of obtaining the lighting level required by Table I are shown on Table C-I, applications C and D. Application C represents several methods of providing the level specified by Item C of Table I, which includes a distance 40 feet outside the fence and 20 feet inside the fence. Application D presents several methods of providing the level specified by Item D of Table I, which includes a distance 30 feet both inside and otuside the fence. No objectionable glare will result on adjacent roads, railroads, etc. from systems of the type indicated.

C-1.4 — *Building Face Boundaries* require adequate lighting over approach areas and up to the building face at all points. In this case, patrol is sometimes maintained outside the building, in which case the path cannot be kept dark. Otherwise, the problem is similar to that described in C-1.2 above and may be simi-

TABLE C-I — Typical Protective Lighting Application Table.

Application Reference	Plant* Classification	Refer to Figure	Luminaire	Lamp Size W = Watts L = Lumens	Location of Luminaire "L" Inside Boundary	Minimum Mounting Height "H" Feet	Spacing "S" Feet
A. Isolated Fenced Boundary (Lighted strip 210 feet wide See Table I)	Critical	5b	Fresnel	500W	10 feet	20	165
	Critical	5b	Fresnel	300W	10 feet	20	110
	Critical	6a	Floodlight Type 2 Spread Lens	500W	80 feet 2 per location	25	225
	Critical	6a	Floodlight Type 2 Spread Lens	300W	80 feet 2 per location	25	180
	Average	5b	Fresnel	500W	10 feet	20	270
	Average	5b	Fresnel	500W	10 feet	20	165
	Average	6a	Floodlight Type 2 Spread Lens	300W	80 feet 2 per location	25	225
B. Isolated Semi-Isolated Fenced Boundary (Lighted strip 80 feet wide See Table I)	Critical	5b	Streetlight Type III	10,000L	10 feet	30	190
	Critical	5b	Streetlight Type I	10,000L	10 feet Tilted 25°	30	170
	Critical	5b	Streetlight Type III	6,000L	10 feet Tilted 10°	25	145
	Critical	5b	Streetlight Type I	6,000L	10 feet Tilted 15°	25	90
	Critical	6a	Floodlight Type 2 Spread Lens	500W	80 feet 2 per location	40	225
	Critical	6a	Floodlight Type 2 Spread Lens	300W	80 feet 2 per location	40	180
	Average	5b	Streetlight Type III	10,000L	10 feet	30	205
	Average	5b	Streetlight Type I	10,000L	10 feet Tilted 25°	30	190
	Average	5b	Streetlight Type III	6,000L	10 feet	25	160
	Average	5b	Streetlight Type I	6,000L	10 feet Tilted 15°	25	130
	Average	6a	Floodlight Type 2 Spread Lens	300W	80 feet 2 per location	40	180
	Average	6b	Floodlight Type 2	200W	10 feet 2 per location	25	150
	Average	6b	Floodlight Type 3	150W	40 feet 3 per location	40	150
C. Non-Isolated Fenced Boundary (lighted strip 20 feet inside & 40 feet outside fence —See Table I)	Critical	5b	Streetlight Type III	10,000L	20 feet	30	190
	Critical	5b	Streetlight Type III	6,000L	20 feet	25	150
	Critical	5b	Streetlight Type III	4,000L	20 feet	25	110
	Average	5b	Streetlight Type III	10,000L	20 feet	30	215
	Average	5b	Streetlight Type III	6,000L	20 feet	25	185
	Average	5b	Streetlight Type III	4,000L	20 feet	25	165
D. Non-Isolated Fenced Boundary (lighted strip 30 feet inside & 30 feet outside fence —See Table I)	Critical	5b	Streetlight Type III	10,000L	30 feet	30	170
	Critical	5b	Streetlight Type III	6,000L	30 feet	25	130
	Critical	5b	Streetlight Type III	4,000L	30 feet	25	110
	Average	5b	Streetlight Type III	10,000L	30 feet	30	215
	Average	5b	Streetlight Type III	6,000L	30 feet	25	175
	Average	5b	Streetlight Type III	4,000L	30 feet	25	150
E. Building Face Boundary (Lighted strip 50 feet wide —See Table I)	Critical	7	Streetlight Type III	10,000L	4 feet outside	30	150
	Critical	7	Streetlight Type III	6,000L	4 feet outside	25	125
	Critical	7	Streetlight Type III	4,000L	4 feet outside	25	110
	Average	7	Streetlight Type III	10,000L	4 feet outside	30	205
	Average	7	Streetlight Type III	6,000L	4 feet outside	25	185
	Average	7	Streetlight Type III	4,000L	4 feet outside	25	155
F. Unfenced Boundary (lighted strip 80 feet wide — See Table I)	Average	7	Streetlight Type III	10,000L	4 feet from building face	30	190
	Average	7	Streetlight Type III	6,000L	4 feet from building face tilted 10°	25	145
	Average	7	Floodlight Type 2 Spread Lens	500W	2 per location at building face	40	225
	Average	7	Floodlight Type 2 Spread Lens	300W	2 per location at building face	40	155
G. Waterfront Boundary (lighted strip 60 feet wide—See Table I)	Critical	8	Streetlight Type III	10,000L	10 Feet†	30	170
	Critical	8	Streetlight Type III	6,000L	10 Feet†	25	115
	Critical	8	Streetlight Type III	4,000L	10 Feet†	25	90
	Critical	9	Floodlight Type 5	500W	50 Feet† 2 per location	60	190
	Critical	9	Floodlight Type 5	300W	50 Feet† 2 per location	60	125
	Average	8	Streetlight Type III	10,000L	10 Feet†	30	200
	Average	8	Streetlight Type III	6,000L	10 Feet†	25	160
	Average	8	Streetlight Type III	4,000L	10 Feet†	25	155
	Average	9	Floodlight Type 5	500W	50 Feet† 2 per location	60	260
	Average	9	Floodlight Type 5	300W	50 Feet† 2 per location	60	180

The requirements of applications C to G may be satisfied by other types of streetlighting distribution if appropriate mounting height, spacing and tilting are selected.

(Table C-I continued on the next page)

*Plant classification shall be as determined by Federal Government Agency.

†Location of waterfront units shall be such that no appreciable shadow is shown on the water by sea wall or bank. U.S. Coast Guard shall be consulted for approval of any proposed lighting adjacent to navigable waters.

TABLE C-I (Continued).

Application Reference	Plant* Classification	Refer to	Luminaire	Lamp Size W=Watts L=Lumens	Location of Luminaire "L" Inside Boundary	Minimum Mounting Height "H" Feet	Spacing "S" Feet
H. Pedestrian Entrance (See Table I)	Any	10b	Streetlight Type IV	15,000L	1 at each of 4 locations	30	12½
	Any	10a	Floodlight Type 6	750W	1 at each of 3 locations	25	25
	Any	10a	Floodlight Type 6	500W	1 at each of 4 locations	25	12½
	Any	10c	Floodlight Type 4	150W	5 at each of 3 locations	25	50
J. Vehicular Entrance (See Table I)	Any	10b	Streetlight Type IV	15,000L	1 at each of 4 locations	30	25
	Any	10a	Floodlight Type 6	750W	1 at each of 3 locations	25	50
	Any	10a	Floodlight Type 6	500W	1 at each of 4 locations	25	25

*Plant classification shall be as determined by Federal Government Agency.

larly handled by method E, Table C-I. This method differs from applications C and D of the same Table only in that luminaires are mounted on the building face, usually by means of pipe brackets. (Fig. 7) Application E will conform with the specifications of item E, Table I.

C-1.5—*Unfenced Boundaries* do not exist at critical plants, and at average plants they are in reality a modification of building face boundaries with the buildings farther from the property line and no fence provided. It is, therefore, desirable to light a somewhat wider strip than in the previous case.

Method F, Table C-I may be used with street lighting luminaires. This method will conform with the specifications of item F, Table I. Otherwise the problem is similar to that described in C-1.2, using method B, Table C-I.

C-1.6—*Water Front Boundaries* present a very special problem where there are navigable channels, and whatever system is chosen should be approved by the U. S. Coast Guard officials before any purchases are made. (Non-navigable water fronts of less than 15 feet in width are similar to and may be handled as are fenced or unfenced boundaries, as indicated.) (Figs. 8 and 9) In all cases the possibility of stealthy approach by water should be considered, and somewhat wider light boundaries are advisable.

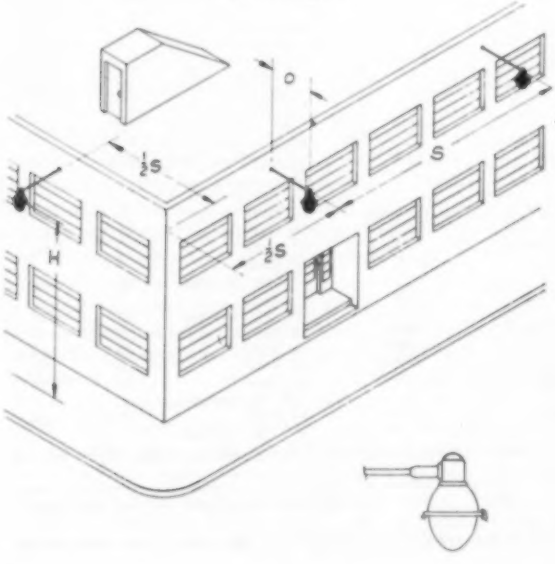
The methods shown under application G of Table C-I conform to the specifications of item G, Table I. Either street lighting luminaires or floodlights may be used to satisfy the lighting level requirement. Luminaires must be mounted high enough and close enough to the water to avoid appreciable shadows of the sea wall or bank being thrown over the water.

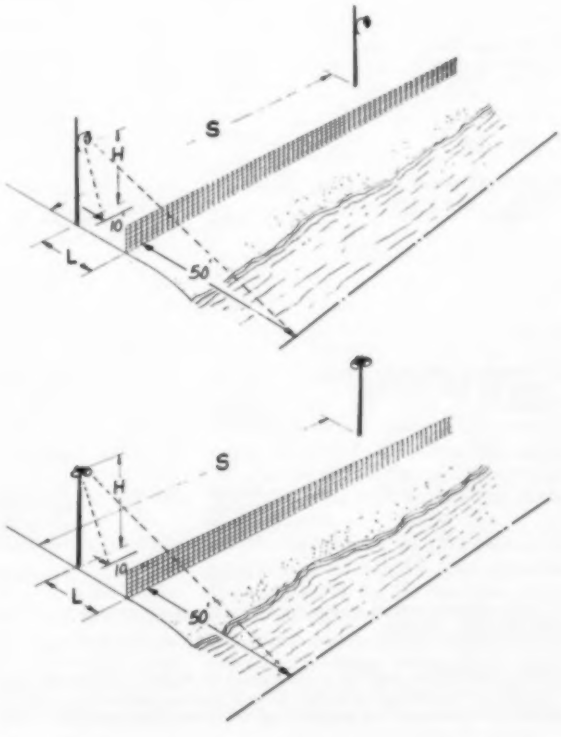
C-1.7—*Entrances* are classified as active or inactive depending on whether or not they are constantly attended and authorized for use at night; and the lighting problem differs only in that auxiliary switching may be used at inactive entrances so that lights are operated only when the entrance is being used. The

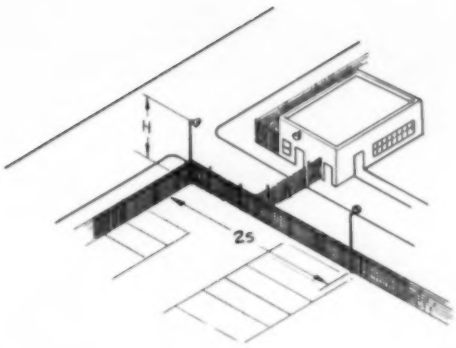
Figure 7. (below) Buildings forming boundary lines using streetlights.

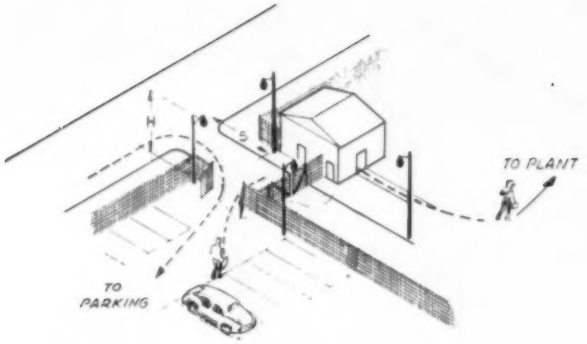
Figure 8. (right) Water-front boundary lighting with streetlights.

Figure 9. (below right) Water-front boundary lighting with floodlights.









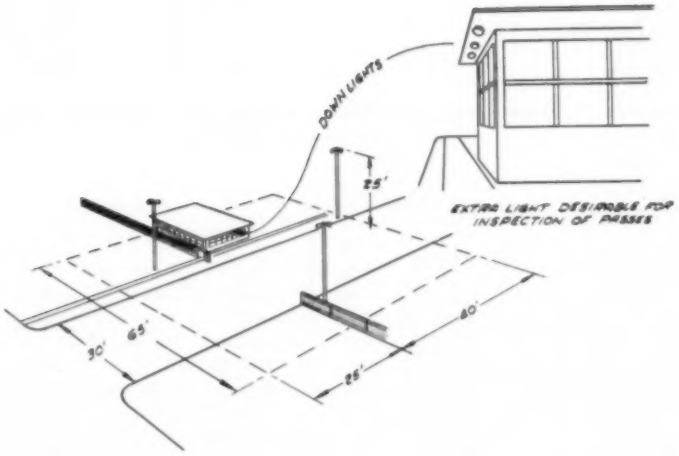


Figure 10a. (above left) Pedestrian and vehicle (active or inactive) entrance using floodlights.

Figure 10b. (above right) Pedestrian and vehicle (active or inactive) entrance using streetlights.

Figure 10c. (left) Pedestrian and vehicle (active or inactive) entrance using floodlights and downlights (PAR-38).

installation suggestions herein otherwise apply to both classes of entrance. (Figs. 10a, b, c).

In the interest of reliability it is recommended that more than one luminaire be used for entrance lighting. Luminaires should be located so as to provide adequate illumination on all vertical surfaces and to extend an appreciable distance inside and outside the entrance gate. Care should be taken to position the lighting equipment in such a manner as to insure a build up of lighting level at the point where passes or credentials are to be closely examined.

At conveyance entrances the area illuminated and the position of the luminaires should be such as to facilitate the complete inspection of trucks, cars, etc., which use the entrance. This requires good vertical illumination on all sides of the conveyance.

The methods of lighting recommended in application H of Table C-I will produce results which conform to the specifications of item H, Table I for pedestrian entrances. Application J of Table C-I indicates several methods of lighting a vehicular entrance to conform to the specifications of item J, Table I.

C-2—*Areas and Structures within Property Lines* — Typical suggested methods designed to meet the specifications of 4.2 are described in succeeding paragraphs. Other installations which will meet the specifications are acceptable.

C-2.1—*Thoroughfares Not Bordered by Buildings* — Thoroughfares within industrial properties which traverse open areas and are not in close proximity to buildings are commonly lighted by streetlighting luminaries. These luminaires may be mounted on poles alongside of the road, and if so mounted, should have asymmetric light distribution (Type II or III) in order to concentrate the light over the road (See Fig. 11a and Table C-II.) If desired, asymmetric units (Type 1) may be utilized, and in such cases, the units would be mounted directly over the center of the road (see Fig. 11b and Table C-II).

In applying street lighting luminaires, either open or closed type, to the problems of lighting roads, the following variable factors must be determined: (a.) light distribution of luminaire; (b.) spacing ratio, (c.) size of lamp in luminaire.

The light distribution of a luminaire is a factor which determines spacing ratio. A distribution should be chosen to deliver maximum light along the

TABLE C-II — Protective Lighting for Thoroughfares.

Application	Refer to Figure	Street Width Feet	Luminaire	Lamp	Mounting Height "H" Feet	Overhang "OH" Feet	Spacing "S" Feet
Thoroughfares bordered by buildings on one or both sides	11a	30	Streetlight Type I	6000	25	15	90
	11a	30	Streetlight Type I	4000	25	15	70
	11b	30	Streetlight Type II	6000	25	2	90
	11b	30	Streetlight Type II	4000	25	2	70
	11b	50	Streetlight Type II or III	10000	30	2	135
	11b	50	Streetlight Type II or III	6000	25	2	80
	11b	50	Streetlight Type II or III	4000	25	2	55
	11b	80	Streetlight Type III or IV	10000	30	2	75
	11b	80	Streetlight Type III or IV	6000	25	2	50
Thoroughfares not bordered by buildings	11a	30	Streetlight Type I	6000	25	15	225
	11a	30	Streetlight Type I	4000	25	15	190
	11a	30	Streetlight Type II	6000	25	2	180
	11a	30	Streetlight Type II	4000	25	2	160

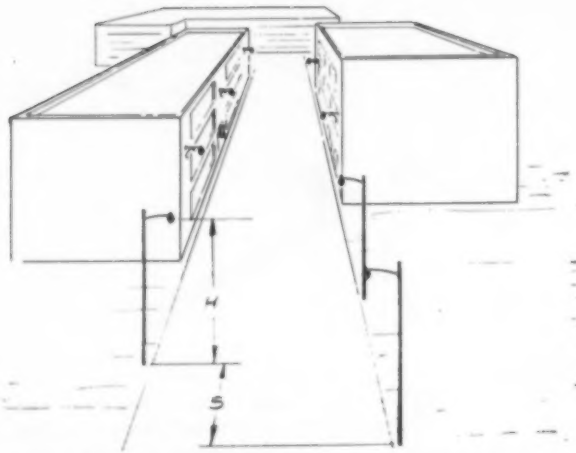


Figure 11a. Thoroughfare lighting with streetlights, side of road mounting.

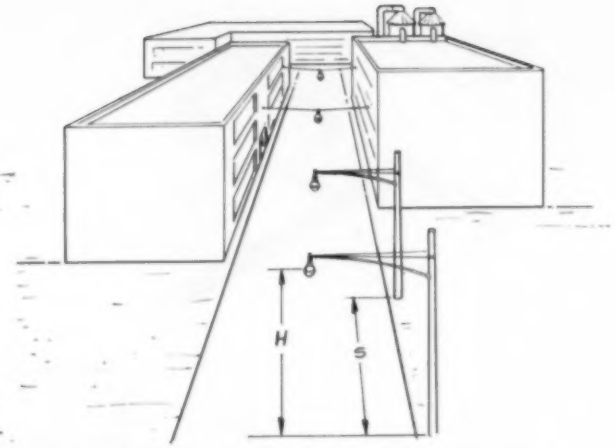


Figure 11b. Thoroughfare lighting with streetlights, center of road mounting.

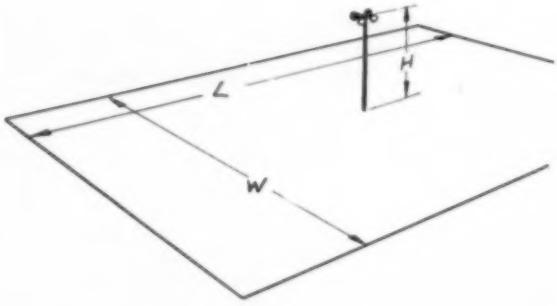


Figure 12a. Open yards or storage area isolated from building using wide spread floodlights.

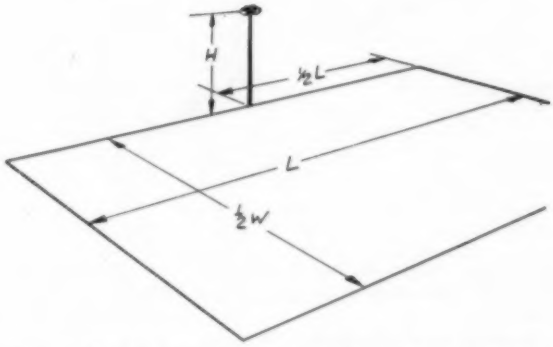


Figure 12b. Open yards or storage area using wide angle floodlights.

thoroughfare, minimize glare, and provide acceptable uniformity of illumination.

If additional information is desired regarding the recommended methods of lighting roadways, refer to "American Standard Practice for Street and Highway Lighting," ASA D.12.1-1953, which provides comprehensive information in regard to the standard types of distribution, mounting height, uniformity of illumination and recommended levels for various traffic densities.

The spacings, mounting heights, and lamp sizes shown in Table C-II are several of the many methods of achieving the level of illumination specified in the Standard, which is 0.05 footcandle minimum at any point.

C-2.2 — *Thoroughfares Bordered by Buildings* — When roads run alongside of buildings or between them a higher level of illumination is specified in the Standard. The same principles of lighting and types of luminaire distribution are suitable as were indicated in C-2.1. In addition to the standard method of pole mounting the luminaires, they may be suspended between the buildings. (Figs. 11a & b)

The spacings, mounting heights, and lamp sizes shown in Table C-II are several of the many methods of achieving the level of illumination specified in the standard, which is 0.20 footcandle minimum at any point.

C-2.3—*Yards* — A low level of general

TABLE C-III — Protective Lighting for Yards and Outdoor Storage Spaces.

Application	Refer to Figure	Luminaire	Lamp Watts	Units per Location*	Mounting Height "H" Feet	Length of Area "A" Feet*	Width of Area "W" Feet*
Outdoor Storage Yards	12a	Floodlight Type 5	1000	4	60	250	250
	12a	Floodlight Type 5	750	4	60	225	225
	12a	Floodlight Type 6	1000	4	40	235	235
	12a	Floodlight Type 6	750	4	40	205	205
	12a	Floodlight Type 6	500	4	40	190	190
	12a	Floodlight Type 6	300	4	40	155	155
Unoccupied Yard Area	12a	Floodlight Type 6	1000	4	60	450	450
	12a	Floodlight Type 6	750	4	60	415	415
	12a	Floodlight Type 6	500	4	40	335	335
	12a	Floodlight Type 6	300	4	40	270	270

*For two luminaires per location as shown in Fig. 12b the width covered is approximately one-half the width covered by four luminaires.

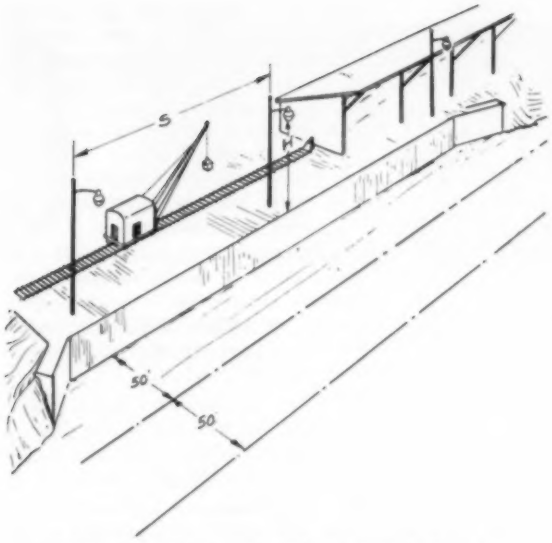


Figure 13a. Piers and docks (street lighting).

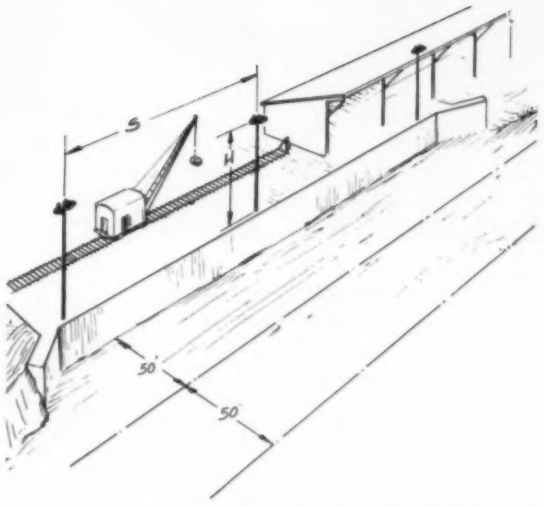


Figure 13b. Piers and docks (floodlighting).

illumination serves protective lighting requirements in open yards. The standard specifies a minimum level at any point of 0.02 footcandle. This may be accomplished by groups of floodlights mounted on poles throughout the area. Fig. 12a and b indicates typical methods of locating luminaires and poles either at the edge of the area to be lighted or at the center of the area. Table C-III indicates the maximum area which can be lighted to meet the specifications with the particular combinations of floodlights, lamp sizes and mounting heights shown. Other types of luminaires, distributions and lamps can be used to provide the specified footcandle level and may be just as acceptable as the methods illustrated.

C-2.4—*Outdoor Storage Spaces* — Lighting for outdoor storage spaces differs from open yards in regard to two items. First the standard specifies a higher minimum illumination level and secondly, the industrial uses of the area may restrict the placement of poles throughout the area. The minimum footcandle level specified is 0.10 footcandle at any point. In general the floodlights may be arranged as per Fig. 12a in which case the dimensions shown in Table C-III indicate the maximum area which can be lighted to meet the specifications with the particular combinations of floodlights, lamp sizes and mounting heights shown. In the event limitations on pole

TABLE C-IV — Protective Lighting for Water Approaches to Piers and Docks.

Application Reference	Plant Classification	Refer to Figure	Luminaire	Lamp Size	Mounting Height "H" Feet	Maximum Spacing "S" Feet	Luminaire per Location
Waterfront	Critical	13a	Streetlight Type III	10,000L	30	180	1
Boundary	Critical	13b	Floodlight Type 5	500W	60	165	2
with Water	Critical	13b	Floodlight Type 5	300W	60	130	2
Approach	Average	13a	Streetlight Type III	10,000L	30	200	
to Dock						Tilted 15°	1
(See Table I	Average	13a	Streetlight Type III	6,000L	25	180	
and Par.						Tilted 10°	1
4.2.4)	Average	13b	Floodlight Type 5	500W	60	220	2
	Average	13b	Floodlight Type 5	300W	60	155	2

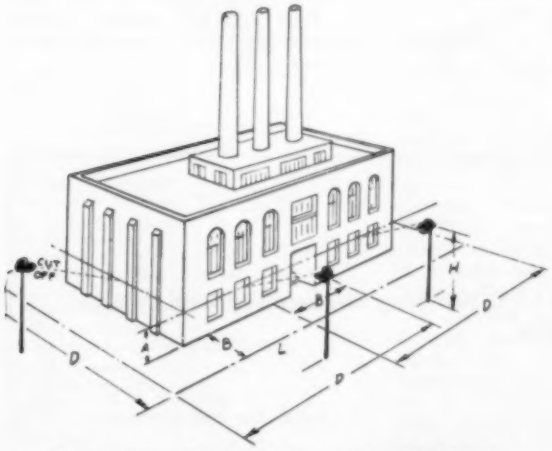


Figure 14a. Vital structures (floodlighting).

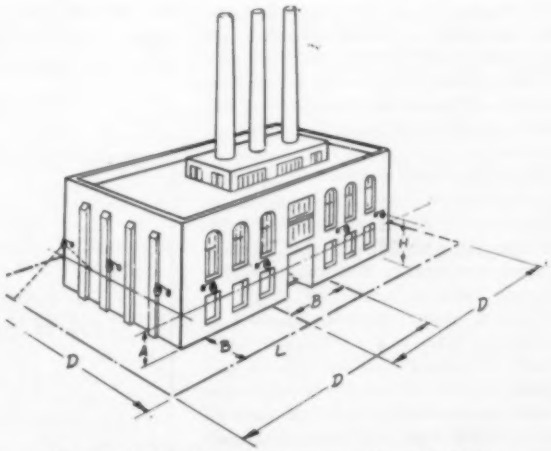


Figure 14b. Vital structures (streetlighting).

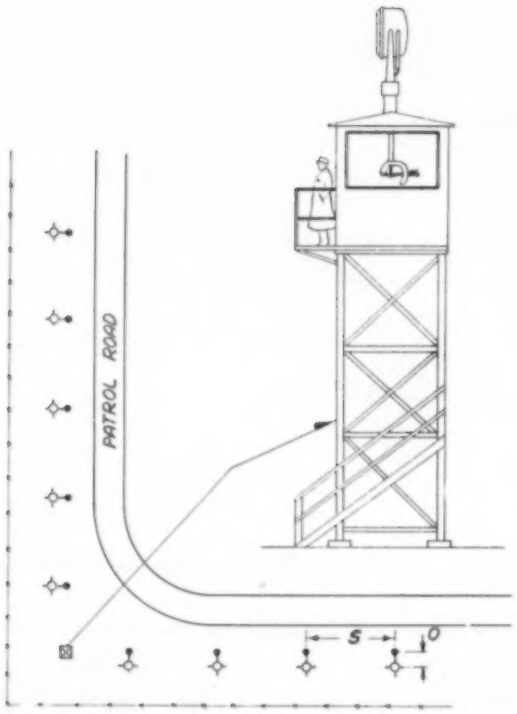


Figure 15. Guard tower with pilot house controlled searchlight.

locations necessitate wider spacings, they may be achieved by using different quantities of units per pole, light distributions and mounting heights.

It should be remembered that this standard and the recommendations of Table C-III are those specified for protective lighting and would not be adequate for material handling or the industrial uses of such storage spaces. In the event outdoor storage spaces are lighted for industrial uses, in all probability all or a portion of the lighting may be used for protective lighting by proper circuiting and control. In the event that lighting equipment normally intended for industrial usage is to provide the protective lighting for the area, action must be taken to insure that such lighting will not be de-energized when productive operations cease.

C-2.5—*Piers and Docks* — Satisfactory lighting for piers and docks may be accomplished by means of either floodlights or suspension luminaires arranged in a manner suggested by Fig. 13a and b. The spacing between luminaires should be such as to provide the levels specified by paragraph 4.2.4 of the Standard, which are 0.10 footcandles on the decks of open piers and 0.05 footcandles on the water approaches extending 100 feet from the pier. Table C-IV lists several methods of applying conventional lighting equipment to achieve these lighting levels.

The area beneath the pier flooring may be lighted with small wattage floodlights arranged to best advanatge with respect to piling. In addition supplementary lighting with searchlights is recommended for guard towers positioned so as to be able to search the water area. For details of such equipment, see also C-3, Supplementary Lighting.

As indicated in C-1.6 water front boundaries present a special problem and whatever system is chosen should be approved by the U. S. Coast Guard before any purchases are made.

C-2.6—*Vital Structures* — Structures which are deemed vital and are to be lighted in accordance with 4.2.5 (a), require individual study in order that the lighting shall meet the requirements of the situation. Two methods illustrated by Fig. 14a and b are suitable.

(a.) Mounting luminaires on the structure itself.

(b.) Mounting of floodlights nearby which are directed at the desired part of the structure.

The purpose of the lighting is to illuminate the lower vertical surfaces of the structure and the area in the immediate vicinity to facilitate in the detection of unauthorized persons approaching or attempting malicious acts.

C-2.7—In the event the area immediately around the structure is very limited or is well lighted from other sources, the method (a) is particularly suitable.

C-3—***Supplementary Lighting*** — Additional light beyond that provided by the fixed lighting is frequently required for investigating unusual or suspicious actions and for general emergency use. Such supplementary lighting facilities are of two kinds. First, a searchlight may be placed at the disposal of the guard. This searchlight is usually of the pilot house control type and mounted on the roof of the guard house (Fig. 15) with the control handle within the guard enclosure. Such a searchlight enables the guard to explore areas inside and outside the plant property and to increase fixed illumination at areas under suspicion. The second type of supplementary lighting consists of some form of portable floodlighting equipment operated from batteries or a gasoline-driven generator. This equipment is useful in providing light at any part of the property of emergency night time construction or repair operations. These portable units vary from a hand lantern type of floodlight to fully equipped emergency trucks supplied with a gasoline-electric set capable of operating lights, pumps, electric tools, etc. Some form of portable lighting equipment adequate for anticipated needs is recommended.

See listing of I.E.S. Sustaining Members beginning on page 18A of this issue.

LIGHTING NEWS

I.E.S. Council Meets Summary of Action

Virtually the full roster of I.E.S. Council members met for the February 14 meeting, at the Park Sheraton Hotel, New York, N. Y. Only one proxy attended, for the Regional Vice-President in the far northwest; all other V-Ps and Directors were present. Council followed a full week of meetings, including the Board of Nominations (to choose a slate for next year's national elections), Regional Activities Committee, and Advisory Board to the President.

Highlights of the all-day meeting included:

New Member Elections

Favorable action on the report of the Board of Examiners resulted in the elections listed elsewhere in Lighting News. Membership statistics, including this action were shown to be as follows:

September 30, 1956		February 14, 1957
8480	Total Membership	8721*
37	Members Emeritus	39**
99	Fellows	97
2123	Members	2167
6036	Associate Members	6228
185	Student Members	190

*Includes 7 Members Retired, 5 Associate Members Retired.
**Includes 10 Fellows, 1 Honorary Member.

Sustaining Members

Thirteen new sustaining members (including one reinstatement) were elected. This was on recommendation of the S-M Committee, Fred Guth, Chairman. Elected were:

Cadillac Electric Supply Co.
431 E. Larned St.
Detroit 26, Michigan.
Official Representative: H. C. Simonton

Columbia Electric & Mfg. Co.
1024 W. Ide Ave.
Spokane, Washington
Official Representative: Walter A. Toly

A. L. Davis Co. Inc.
101 Central Ave.
Newark, N. J.
Official Representative: Arthur L. Davis

Fischbach, Moore & Morrissey, Inc.
173 West Madison St.
Chicago 2, Illinois
Official Representative: J. R. Meehan

Thomas Keegan
20 Springdale Ave.
Massapequa, L. I., New York
Official Representative: Thomas J. Keegan

Kliegl Bros.
321 W. 50th St.
New York 19, N. Y.
Official Representative: Robert A. Langer

Koehler Electrical Supply Co. Inc.
284 Greenwich St.
New York, N. Y.
Official Representative: Harold C. Hollowell

LaSalle Electric Supply Co.
20216 John R. Street
Detroit 3, Michigan
Official Representative: A. H. Gatward

MacNutt Electric Co. Inc.
420 Lexington Ave.
New York 17, N. Y.
Official Representative: M. R. Minto

The Mitis Company Limited
5 St. John St.
Rimouski, Que., Canada
Official Representative: J. Henri Labrie

Philip Little Lighting Studio
170 Southdale
Edina 10, Minnesota
Official Representative: Donald D. Olson

Tarnow Electric Supply Co.
34 E. Milwaukee Ave.
Detroit, Michigan
Official Representative: Nathan Tarnow

Wald & Zigas
42-40 27th St.
Long Island City 1, N. Y.
Official Representative: Henry J. Wald

Technical Reports

Several reports were submitted to Council, and were accepted for letter ballot.

Report No. 6 of the Q and Q Committee, Glenn A. Fry, Chairman. "Avoidance of Direct Discomfort Glare in the Design of Lighting Installations."

Industrial Lighting Committee Report, W. H. Kahler, Chairman: "Lighting of Indoor Locations of Central Station Properties."

A report on the Testing of Searchlights, and also for the Testing of Fluorescent Lamps, were presented, and also a Guide for Daylight Survey.

Committees

A number of Committees reported on their activities, outlining to Council status of their various projects. Some of these included: Regional Activities, G. J. Taylor, Chairman; Publications, J. S. Schuchert; Procedures and Policies, G. W. Beals; Membership, Brooks Chassaing; National Technical Conference, C. L. Amick (speaking for J. C. Forbes); Finance, W. B. Lowell, Jr.

A new task committee was appointed to study the possibility of a full-scale survey-census of I.E.S. membership. Making this study will be W. P. Lowell, Jr., J. S. Schuchert and Brooks Chassaing. Another task committee appointed covers Student Members, full scope to be reported later, with Walter Sturrock as Chairman.

Conference Planned for Engineer Development Program

An all-day conference is being scheduled for April 4, by the Management Division of the Cleveland Engineering Society. The conference is aimed at pointing up the need for the adoption by industrial management, professional engineering groups and area educational institutions of a definite program for accelerated development of engineers. The meeting will be held at the Society's building, 2136 East 19th St., Cleveland 15, according to an announcement by Michael S. Shane, chairman of the Management Division.

Training Course in Illumination Offered by Westinghouse

A new lighting training course, "Modern Illumination, Fundamentals, Techniques, Applications," has been prepared by the Westinghouse Lamp and Lighting Divisions. The course has been designed for new and experienced utility salesmen as well as other members of the lighting industry.

The eighteen lessons consist of audio-visual presentations using sound slide films and records. Eighteen separate lesson books, an instructor's manual and a handbook are supplied.

Subjects covered in the course are:

1. Mechanism of the Human Eye
2. Light and Vision
3. Illumination Terminology
4. Quantity Requirements of Good Illumination
5. Quality Requirements of Good Illumination
6. Importance of Color in Illumination
7. Incandescent Lamps
8. Mercury and other Electric Discharge Lamps
9. Fluorescent Lamps
10. Principles of Light Control
11. Systems of Light Control
12. Calculation of Interior Illumination
13. Office Lighting
14. School Lighting
15. Store Lighting
16. Industrial Lighting
17. Floodlighting
18. Cost and Maintenance of Lighting.

A course of this nature was first made available by Westinghouse after World War II and was widely used for training in lighting sales and applications. The present course has been revised to in-

clude new and improved light sources and equipment, improved methods of application, and new recommendations.

A class of ten members is said to require one complete kit of materials, for which the price is $250. Further information may be obtained from Westinghouse representatives or the Lamp Division, Westinghouse Electric Corp., Bloomfield, N. J.

On the National Ballot

The following slate of officers and directors was selected by the National Board of Nomination, E. M. Strong, Chairman, at their meeting February 13.

For President, 1957-1958

Kirk M. Reid

Senior Illuminating Engineer, Application Engineering, Large Lamp Dept., General Electric Co., Cleveland, Ohio.

Fellow of the Society since 1948, Society membership dates from 1928. Previous national offices include Treasurer, 1952-1954, General Secretary 1954-1955 and Vice-President 1955-1957.

Active in the Society's technical committees, including Defense, Progress, Papers, Sports and Recreational Area Lighting, and Street and Highway Lighting. Author of numerous technical papers principally in the area of highway lighting, he has been responsible for the Society's active part in the National Shade Tree Conferences.

Current committee assignments include Chairman, President's Advisory Board, member, Council Executive Committee. During 1955-1956 he was an active member of the Golden Anniversary Committee and Chairman of the Regional Activities Committee.

For Vice-President, 1957-1959

Joe B. Browder

Sales Manager, Georgia Power Co., Atlanta, since 1955, this appointment following a number of positions such as Division Lighting Engineer and Manager of the Lighting Division.

Membership in Society dates from 1941 with transfer to Member grade in 1945. Vice-President of the Southern Region 1948-1951 following active part in Georgia Section of which he was Chairman 1946-1947.

National Treasurer, 1956-1957, and during the past ten years member of national committees including Sustaining Membership, Street & Highway Lighting, Constitution and By-Laws, Professional Requisites. Chairman of the 1957 Executive Committee for the National Technical Conference scheduled in Atlanta.

For General Secretary, 1957-1958

Richard G. Slauer

Product Sales Manager, Fixture Division, Sylvania Electric Products Inc., Wheeling, West Va., since May 1956, following thirty years in development, commercial, field and production engineering with his present company since 1944 as well as with the General Electric Co. and Westinghouse Electric Corp.

Since 1949 a Fellow of the Society, his first membership dates from 1930. Previous national offices include General Secretary 1956-1957 (to which he is renominated) and Vice-President, Northeastern Region 1950-1952.

Service in Society's committees has been both in the technical and non-technical areas, including Publications (Chairman 1945-1948), Interior Lighting of Public Conveyances (Chairman 1945-1946), I.E.S. Lighting Handbook, Membership (Chairman 1951-1952), Project Planning and Street and Highway Lighting.

Also very active in the Society's two National Technical Conferences in Boston serving as Executive Committee Chairman in 1948 and in 1956 as Vice-Chairman. Active in the American Institute of Electrical Engineers and a Past Section Chairman at Lynn, Mass.

For Treasurer, 1957-1958

James R. Chambers

Manager, Advertising and Sales Promotion, Benjamin Electric Manufacturing Co., Des Plaines, Ill. since 1951 and prior to that application research engineer.

Originally elected to membership in 1941 he transferred to Member grade in 1946. Active in the Chicago Section he served as its Chairman 1953-1954. Vice-President of the Midwestern Region 1954-1956 and during that period member of the Regional Activities Committee.

Principal committee assignments include Industrial Lighting (Chairman 1953-1954), Public Relations and Information (Chairman 1956-1957), Lighting Service and Publications Committees.

Address Changes should be reported to I.E.S. Headquarters by the first of any month, to insure the uninterrupted mailing of I.E. and other Society communications.

For Director, 1957-1960

J. Dixon Mitchell

Lighting Engineer, Lamp Division, Westinghouse Electric Corp., since 1948 Region Engineer, Southeastern Region, Chamblee, Ga.

Elected to Society membership in 1939 and transferred to Member grade in 1950. Former member of the New York and St. Louis Sections, since 1948 active in Georgia Section, which he served as chairman during 1952-1953. Vice-President of the Southeastern Region 1955-1957.

A Registered Professional Engineer in Georgia and member of the Society of Professional Engineers, both in Georgia and nationally; also Member of the American Institute of Electrical Engineers.

For Director, 1957-1960

Jerry D. Whitnell

Commercial Sales Engineer, General Sales Department, Arizona Public Service Company, Phoenix, Ariz.

Membership in the Society dates from 1950 with transfer to Member Grade in 1951. Active in Arizona Section, following organization of Arizona Chapter when he served as Chairman pro-tem. Vice-President, Inter-Mountain Region 1955-1957. Current committee assignments include Regional Activities and Allied Arts.

SCHEDULED EVENTS

March 28-29, 1957 — Pacific Northwest Regional Conference, Illuminating Engineering Society, Empress Hotel, Victoria, B. C.

April 3, 1957 — Society of Plastics Engineers, Regional Technical Conference, New York, N. Y.

April 3-5, 1957 — South Pacific Coast Regional Conference, Illuminating Engineering Society, Hotel Statler, Los Angeles, Calif.

April 8-11, 1957 — Fourth National Electrical Industries Show, 71st Regiment Armory, New York, N. Y.

April 11-12, 1957 — Inter-Mountain Regional Conference, Illuminating Engineering Society, Alvarado Hotel, Albuquerque, N. M.

April 14-17, 1957 — Building Research Institute, Drake Hotel, Chicago, Ill.

April 18, 1957 — I.E.S. Council Meeting, New York, N. Y.

April 28-30, 1957 — Southwestern Regional Conference, Illuminating Engineering Society, Holiday Inn, Oklahoma City, Okla.

April 29 - May 3, 1957 — Society of Motion Picture and Television Engineers, Shoreham Hotel, Washington, D. C.

April 30 - May 2, 1957 — National Association of Lighting Maintenance Contractors, Conference, Kansas City, Mo.

May 2-3, 1957 — Spring Technical Conference, I.E.S. Aviation Lighting Committee, Carvel Hall Hotel, Annapolis, Md.

May 6-8, 1957 — Air Conditioning and Refrigeration Institute, Annual Meeting. The Homestead, Hot Springs, Va.

May 7-9, 1957 — Chicago Electrical Industry Show, Chicago, Ill.

May 9-10, 1957 — Midwestern Regional Conference, Illuminating Engineering Society, Hotel Pfister, Milwaukee, Wis.

May 12-16, 1957 — The Electrochemical Society, Inc., Hotel Statler, Washington, D. C.

May 13-14, 1957 — Great Lakes Regional Conference, Illuminating Engineering Society, Pantlind Hotel, Grand Rapids, Mich.

May 15-17, 1957 — Pacific Coast Electrical Association, Inc., Annual Convention, Fairmont Hotel, San Francisco, Calif.

May 16-17, 1957 — Canadian Regional Conference, Illuminating Engineering Society, Hotel Sheraton Brock, Niagara Falls, Ont.

May 20-24, 1957 — National Fire Protection Association, Annual Meeting, Statler Hotel, Los Angeles, Calif.

May 23-24, 1957 — East Central Regional Conference, Illuminating Engineering Society, William Penn Hotel, Pittsburgh, Pa.

May 26-29, 1957 — National Association of Electrical Distributors, Sheraton-Park and Shoreham Hotels, Washington, D. C.

June 4-6, 1957 — Chicago Electrical Industry Show, Conrad Hilton Hotel, Chicago, Ill.

June 12, 1957 — I.E.S. Council Meeting, New York, N. Y.

June 13-14, 1957 — Northeastern Regional Conference, Illuminating Engineering Society, Hotel Statler, New York, N. Y.

June 14, 1957 — Society of Plastics Engineers, Regional Technical Conference, M.I.T., Cambridge, Mass.

June 24-27, 1957 — American Society of Heating and Air-Conditioning Engineers, Murray Bay, Quebec, Que.

June 24-28, 1957 — American Institute of Electrical Engineers, Summer General Meeting, Montreal, Que.

August 28-30, 1957 — American Institute of Electrical Engineers, Pacific General Meeting, Yakima, Wash.

September 9-13, 1957 — Illuminating Engineering Society, National Technical Conference, Biltmore Hotel, Atlanta, Ga.

September 24-26, 1957 — Institute of Traffic Engineers, Statler Hotel, Detroit, Mich.

October 4-9, 1957 — Society of Motion Picture and Television Engineers, Hotel Sheraton, Philadelphia, Pa.

October 5-8, 1957 — International Association of Electrical Leagues, Sinton Hotel, Cincinnati, Ohio.

October 7-9, 1957 — National Electronics Conference, Inc., Hotel Sherman, Chicago, Ill.

October 7-11, 1957 — American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 9-11, 1957 — Canadian Electrical Manufacturers Associaiton, Sheraton-Brock Hotel, Niagara Falls, Ont.

October 21-25, 1957 — National Safety Council, 45th National Safety Congress & Exposition, Chicago, Ill.

October 28-31, 1957 — National Association of Electrical Distributors, (Semiannual Meeting), Edgewater Beach Hotel, Chicago, Ill.

October 27-30, 1957 — National Association of Electrical Distributors (Board of Governors), Skytop Lodge, Skytop, Pa.

Week of November 10, 1957 — National Electrical Contractors Association, Cincinnati, Ohio.

November 11-15, 1957 — National Electrical Manufacturers Association, Traymore Hotel, Atlantic City, N. J.

November 18-21, 1957 — 10th Exposition of the Air-Conditioning and Refrigeration Industry, Navy Pier, Chicago, Ill.

I.E.S. National Technical Conferences

1957 — September 9-13 — Biltmore Hotel, Atlanta, Georgia

1958 — August 17-22 — Royal York Hotel, Toronto, Ontario

1959 — September 7-11 — Hotels Fairmont and Mark Hopkins, San Francisco, California

Wiring Design — Topic Of Pittsburgh Section Course

A series of twelve weekly two-hour meetings are being sponsored by the Pittsburgh Section of I.E.S. and the Electric League of Western Pennsylvania, on the subject of Wiring Design. Classes are being held at the Duquesne Light Co. building.

Sessions, which include question and discussion period, are as follows:

February 11 — Electrical Fundamentals.
February 18 — Electrical Formulas.
February 25 — Wiring Codes.
March 4 — Electrical Conductors.
March 11 — Electrical Systems.
March 18 — Parts of Wiring System.
March 25 — Wiring Materials.
April 1 — Designing the Lighting Wiring System.
April 8 — Residential Wiring.
April 15 — Commercial Lighting Wiring.
April 22 — Industrial Wiring.
April 29 — Industrial Wiring, continued.

Applications for Retired Membership

By action of the membership of I.E.S., the new retired membership classifications became effective in the fiscal year beginning October 1956. Privileges in these new grades, earned by long membership in the Society, include reduced annual dues ($5.00) with continued receipt of all Society mailings including ILLUMINATING ENGINEERING. Such members will be designated as Member, Retired; Associate Member, Retired.

Those who are interested and qualified (at least thirty years of membership and 65 years of age) should address a letter to the General Secretary, at Society Headquarters, stating that they have retired from regular occupation in business or profession.

Mutual Aims Emphasized By Five New Sustaining Members

Representatives from five "branches" of lighting signified their joint interest in the application of good lighting principles, by simultaneously becoming Sustaining Members of I.E.S. The "mass signing" of application blanks took place at a special luncheon meeting February 6, at the Park Sheraton Hotel, New York City. Signing up as sustaining members were:

Architect — Thomas J. Keegan, Massapequa, N. Y.

Lighting Equipment Manufacturer — Robert A. Langer, Kliegl Bros., New York, N. Y.

Consulting Engineer — Henry J. Wald, Wald & Zigas, Long Island City, N. Y.

Distributor — Harold Hollowell, Koehler Electrical Supply Co., New York, N. Y.

Contractor — M. R. Minto and William Morahan, Macnutt Electric Co., New York, N. Y.

Present also at the luncheon were the Vice-President of I.E.S., George J. Taylor of Day-Brite Lighting Inc.; the electrical trade press represented by Hugh Scott, Industrial Editor of *Electrical Construction and Maintenance;* the I.E.S. New York Section Chairman, G. G. Rae, of Holophane Company, Inc.; N. Y. Section Sustaining Membership chairman, M. H. Silverman, Fluores-O-Lite Co., Hillside, N. J.; and four members of the I.E.S. headquarters staff: C. L. Crouch, Technical Director; C. E. Ellis, Advertising and Promotion Manager; A. D. Hinckley, Executive Secretary; and Ruby Redford, Editor of ILLUMINATING ENGINEERING.

It was pointed up at the meeting that two-thirds of all new Sustaining Member dues will be allocated to the Illuminating Engineering Research Institute. In addressing the group, Mr. Taylor noted that besides the five represented at this meeting, numerous other professions and industries are vital parts of the lighting industry, and lend their support also to the objectives of I.E.S. and illumination research, as Sustaining Members of the Society. Some of these include public utilities, lamp manufacturers, interior decorators, vision specialists, accessory manufacturers and many others.

SIGNING as new Sustaining Members of I.E.S. are, left to right, Thomas J. Keegan, architect; Robert A. Langer, equipment manufacturer; Henry J. Wald, consulting engineer; Harold Hollowell, distributor; and M. R. Minto, contractor. Standing are M. H. Silverman, Sustaining Membership chairman of New York Section and Section Chairman Gene Rae.

Street Lighting Forum Sponsored in Montreal

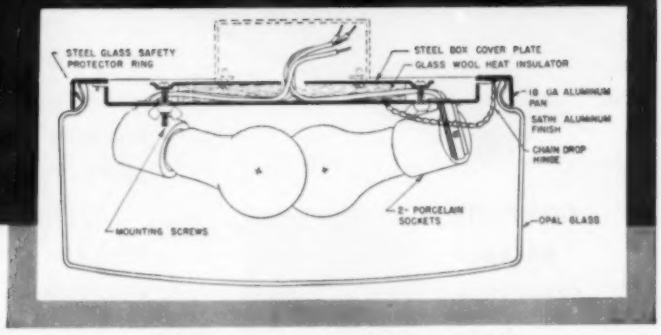
The Montreal Section of I.E.S. and the Electrical Club of Montreal joined on February 20 in holding a forum on street lighting. Chairman of the Forum was C. E. Mertens, Canadian General Electric Co., Chairman of the Section's Education Committee.

Luncheon speaker was I.E.S. President Marshall N. Waterman, whose topic was "Street Lighting and the Utility." The forum continued with:

I.E.S. Standards on Street and Highway Lighting — Joe Thomas, Canadian Regional V-P.

The Need for Good Street Lighting — Warren Edman, Holophane Co., Ltd.

(*Continued on page* 13A)



Perfeclite now offers a new **hammer lock** design in incandescent ceiling pan lighting fixtures. No other ceiling pan fixture on the market today has all these engineering features:

- Globe opens on **hinge** for quick easy cleaning and relamping.
- Unique **safety locking fitter** holds globe in place without bothersome screws, unsightly extensions or trick springs. Globe is secured with lugs by simple twist of the wrist.
- Lip of globe is completely protected against breakage by a **steel protector ring.**
- Provides **ceiling illumination** as well as **evenly distributed floor lighting.**
- Minimum amount of metal, maximum amount of glass results in **highest light efficiency.**

Here is a unique ceiling pan fixture design for either commercial or residential installation. For further information send for The Perfeclite Data Sheet 56-C today.

Perfeclite's new **hammer lock** fixture is available in the following sizes:

Model	Glass Diameter	Wattage
HH-9	8"	2- 40 W
HH-11	10"	2- 60 W
HH-13	12"	2- 75 W
HH-15	14"	2-100 W
HH-17	16"	3-100 W

Send for new Perfeclite Catalog 956 giving full information on our entire line of Commercial Incandescent Fixtures and Exit Units.

Fixtures are Underwriters Laboratories, Inc. approved.

*Patent pending

THE PERFECLITE COMPANY

1457 East 40th Street • Cleveland 3, Ohio

☐ **Please send me The Perfeclite Data Sheet 56-C.**

☐ **Please send me the new Perfeclite Catalog 956.**

Name.....

Address.....

City..... .....State.....

PERFECLITE PRODUCTS
THE MARK OF LIGHTING SERVICE

Jefferson Ballast for 800 MA High Output Fluorescent Lamps

This Jefferson Ballast is designed to give you Full-Rated light output as specified by the lamp manufacturer.

Only Jefferson has succeeded in *designing* and *manufacturing* a ballast for two HO 96T12/RS or two HO 72T12/RS lamps capable of giving *full light* output.

Applications include medium and high bay industrial and commercial locations where high output is required.

It is recommended that surface mounted fixtures be checked for conformance to UL temperature requirements.

Remember—for full light output from the new High Output lamps, insist on Jefferson Ballast No. 254-721!

COMPLETE BALLAST SELECTION DATA

New Technical Bulletin B560-10 gives complete selection data on the entire Jefferson Ballast line in compact, easy-to-use form. Write for your copy today!

PRIMARY 118 VOLTS*—60 CYCLES—HIGH POWER FACTOR

Catalog No.	Watts	Lamps	MA	Approx. Watt Loss	Sound Group	Minimum Operating Temperature	Net Weight
254-721	(2)100/105	(2)96T12/RS	800	38	F	+50°F	13 Lbs.
	(2)85	(2)72T12/RS	800			−20°F	

Length 14 5/16", Width 3⅛", Height 2⅝", Mtg. Centers 13¾".

*For 277 Volt lines, specify Catalog No. 254-728.

Jefferson Electric Company

BELLWOOD, ILLINOIS

(*Continued from page 10A*)

Mercury and Fluorescent Sources for Street Lighting — E. T. Morwick, Canadian Westinghouse Co.

Modern Fluorescent Street Lighting Equipment — D. H .Grills, Canadian General Electric Co.

Modern Mercury Street Lighting Equipment — W. Hawley, Powerlite Devices Ltd.

Considerations in Planning and Maintenance of Street Lighting Installations — J. Rousseau, City of Montreal.

Practical Problems of Street Lighting Installations — G. Presseau, Bedard & Girard Ltd.

The luncheon and forum were held in the Spanish Room of the Queen's Hotel, Montreal.

Back Issues of I.E. Available

For a limited time only, back issues of I.E. — back to 1936 — are reported available, from Paul Fisher, Commercial Engineer, Public Service Co., Division of Commonwealth Edison Co., 10 Main St., Aurora, Ill.

RECENT meeting of the Montreal Section of I.E.S. featured Don P. Caverley, Sylvania Electric Products, who spoke on "Colour in Lighting." Meeting was held in the Auditorium of the Physical Science Center, McGill University, Montreal.

A.I.A. Announces Contest On "Homes for Better Living"

A contest for home owners, architects, and builders in the eastern United States, with the theme of "Homes for Better Living," has been announced by the American Institute of Architects. This is the second annual awards program of A.I.A., and this year the program is in cooperation with *Better Homes & Gardens* and *House and Home* magazines and the National Broadcasting Co.

In a continuing attempt to upgrade home design in the United States, the A.I.A. is surveying a separate area of the country each year. Last year, with its annual convention in Los Angeles, the Institute studied West Coast achievements in home design. This year the East was chosen. Award winners will be announced at a banquet during the A.I.A. 100th anniversary celebration in Washington, D. C., May 14-17. Deadline for preliminary entries was February 15.

(*Continued on page 14A*)

An Open Invitation to I.E.S. Members

Membership in the Illuminating Engineering Society has many advantages and personal satisfactions for you. We invite YOU to bring these advantages to others by seeking their membership also. Through your Section or Chapter Membership Committee, you can help offer to others the following advantages in I.E.S. membership which you yourself now enjoy.

- Valuable Contacts. Through attendance at Section and Chapter meetings, I.E.S. members are acquainted with people from all segments of the lighting profession and industry; from Research through Teaching, Application, Specification, Manufacture, Distribution, to final installation and use.
- Lighting Trends and Information. Through lectures and forums sponsored by their Section, Chapter or Region, I.E.S. members get information on current and developing lighting techniques.
- Recognition. From the platform, at local, regional or national meetings, I.E.S. members can present their own views, studies and contributions to the science or the practical application of lighting.
- Monthly Magazine. The Society's journal ILLUMINATING ENGINEERING includes not only the literature of lighting—Recommended Practice, reports, Conference papers — but also articles and up-to-date information on the practical everyday application of lighting knowledge.
- Lighting Library. I.E.S. members have access to a complete selection of the publications of our Society; reference material for all current lighting application problems.
- Participation. The satisfaction of working together with others in your field is by no means the least of the advantages of I.E.S. membership.

We invite YOU to invite others within your area to join I.E.S. Membership blanks are available from your local Membership Committee.

1956-1957 National Membership Committee.

WHAT'S AHEAD was the topic of speaker J. F. Whitehead, who discussed developments in lighting and lamps, aided by a luminous crystal ball, at the December 20 meeting of the St. Louis Section. Left to right in photo are: Joe Chassaing; H. Poehling; Robert Welch, Section Chairman; Mr. Whitehead; Brooks Chassaing; D. J. Biller; Charles Zurheide and Dick Cohen.

(Continued from page 13A)

A house may be submitted to the contest by its owner, architect or builder. Each entrant must indicate that he has the approval of the other two parties involved. Every entry must be designed by a registered architect, who need not be a member of A.I.A. Each house must be completely finished at the time of entry and must have been built since January 1954.

16-Week Course on Fundamentals Held at University of Colorado

The Denver Extension Center of the University of Colorado is holding a 16-week course, two hours every Monday from February 11 through May 27, on Fundamentals and Techniques of Lighting Practice. Classes are being held at the Tramway Building.

G. B. Buck, District Engineer, General Electric Lamp Division, is Instructor for the classes, which cover the following topics.

February 11 — Elementary Physics of Radiation. The three dimensions of light.
February 18 — Incandescent Lamps and Circuits.
February 25 — Mercury Lamps and Circuits.
March 4 — Fluorescent Lamps and Circuits.
March 11 — Other Light Sources and Applications.
March 18 — General Lighting Design.
March 25 — Light and Life.
April 1 — Industrial Lighting Practice.
April 8 — Office and School Lighting Practice.
April 15 — Commercial, Display and Theatrical Lighting.
April 22 — Fixture Design and Photometry.
April 29 — Lighting Economics and Cost Analyses.
May 6 — Wiring and Circuits.
May 13 — Other Lighting Fields (Home and Garden, Outdoor, Sports, Street, Photography).
May 20 — New Techniques in Lighting.
May 27 — Refresher Symposium.

Tuition for the entire course is $18. Under consideration by the University is a more advanced course, to be presented during the fall semester beginning in September.

ABOUT PEOPLE

Svend Bruun, formerly Chief Engineer with Rambusch Lighting, has established practice as a Consulting Illuminating Engineer, with offices at 626 Frederick St., Ridgewood, N. J., and 420 Lexington Ave., New York 17, N. Y. Mr. Bruun is currently chairman of the I.E.S. General Board of Examiners.

Sylvania Electric Products Inc., Salem, Mass., has announced several new appointments in the Lighting Division. **Paul F. Cameron** has been named to the post of manufacturing manager, special products, and will be responsible for the manufacturing operations of the plants at Waldoboro, Me.; Ipswich, Mass., and Salem. **Alton C. Kendall** has been appointed to the new position as operations manager, fixtures. Mr. Kendall, who has been manager of the company's Wheeling, W. Va., fluorescent fixture plant, will continue to make his headquarters there. **Robert E. Betts** has been named manager of manufacturing services for the Lighting division, directing the division's mechanical development, purchasing and overall industrial engineering functions. **Adolph A. Weeks** has been appointed to the newly created post of plant manager of the starter and coil plant at Waldoboro. Mr. Weeks was previously manufacturing superintendent of the Waldoboro operation.

The election of **C. R. Hosey** and **John W. Wade** to Vice-Presidents of the John C. Virden Co. has been announced. Mr. Hosey has been made Vice-President in charge of Sales Development and Mr. Wade has been made Vice-President, Manufacturing.

Harold F. Wall has been appointed to the office of General Superintendent of the Public Lighting Commission of the City of Detroit, succeeding **A. M. Lorenz,** who is retiring this July 1. Mr. Wall is a member of the I.E.S. Committee on Street and Highway Lighting and member or chairman of numerous of its subcommittees. He has recently been named to the United States National Committee of the C.I.E. and is on the National Technical Society, Street Lighting.

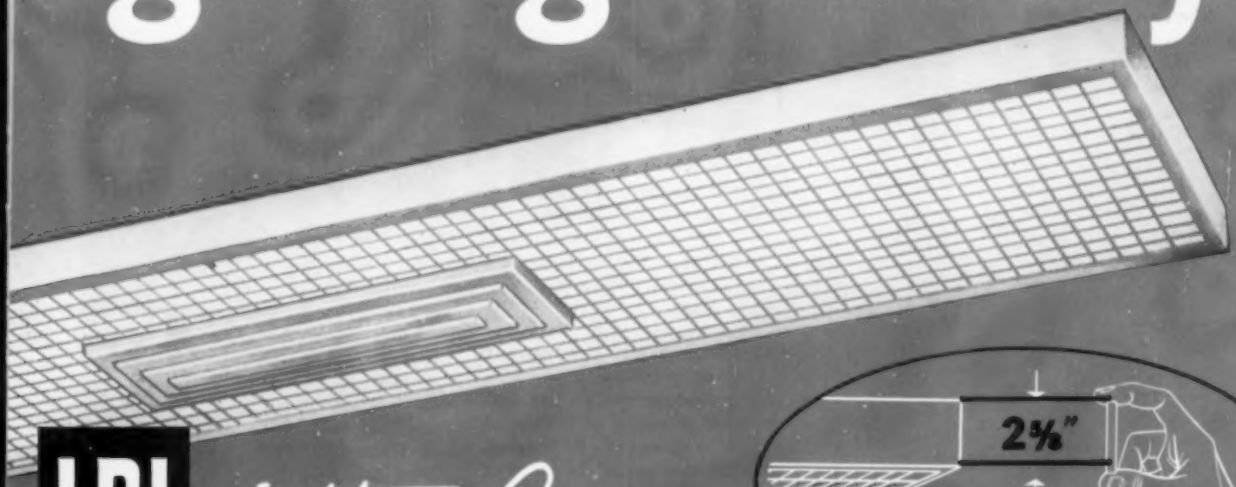
The establishment of an organization devoted exclusively to the development of electroluminescence has been announced by the Westinghouse Lamp Division. The organization changes will involve commercial development, applied and basic research. Appointed to a new post to coordinate "Rayescent" activities is **Carl F. Jensen.** Active in the lighting field for many years, Mr. Jensen has been named manager of "Rayescent" lighting. Heading the commercial engineering section is **George B. Saviers,** who has been transferred from the company's Television-Radio Division. To accelerate development, a new applied research group has been established. This group of engineers and technicians will report to **Dr. John W. McNall,** assistant director of research. The group will work on the development of both glass and enamel (metal) type electroluminescent cells and will be concerned with improvement of maintenance and efficiency, and the application of transistor circuits to "Rayescent" lighting. In addition to the applied research section, a basic research group, which is part of the phosphor research section under **Dr. Henry F. Ivey,** section manager, will conduct pure research. Personnel who will comprise the nucleus of the new applied research section include **Robert W. Wollentin,** research engineer; **Blanchard A. Perry,** applied research engineer; **Derrick C. Bell,** applied research engineer; and **Ivan E. Buck,** ceramic engineer.

Officers of the Society of Plastics Engineers were elected at the January meet-

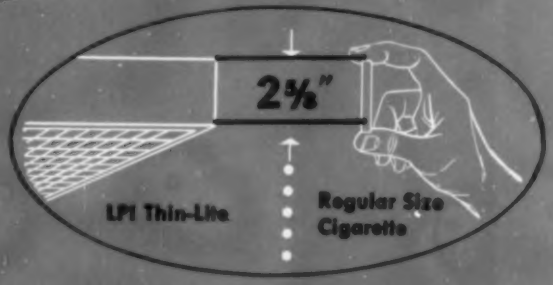
(Continued on page 16A)

It's making

lighting history!



LPI *Thin-Lite*



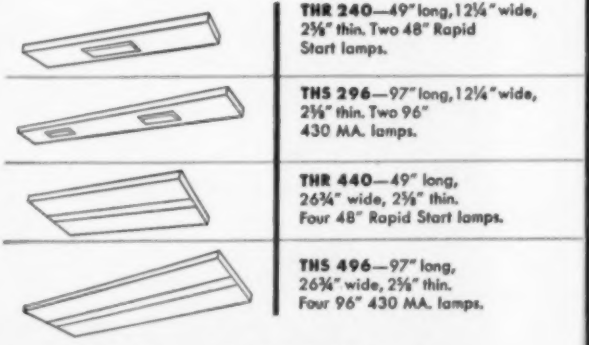
World's Thinnest Shielded Luminaire

No wonder Thin-Lite is creating such a sensation from coast to coast. Here, at last, is a surface mounted fixture so shallow that its depth below ceiling is essentially the same as that of troffers fitted with dished shields. Thin-Lite actually creates a semi-recessed effect.

The four different models (right) can be mounted end to end or side by side, in any combination, to form an unlimited variety of lighting patterns up to any desired size. A few suggestions are shown below.

Thin-Lite luminaires feature metal-framed, molded plastic louver panels, secured by LPI's patented floating hinge which cannot be seen from any angle, and which eliminates unsightly latches and fastening devices.

Available through leading electrical wholesalers, Thin-Lite luminaires are wired with standard E.T.L. ballasts.



THR 240—49" long, 12¼" wide, 2⅝" thin. Two 48" Rapid Start lamps.

THS 296—97" long, 12¼" wide, 2⅝" thin. Two 96" 430 MA. lamps.

THR 440—49" long, 26¾" wide, 2⅝" thin. Four 48" Rapid Start lamps.

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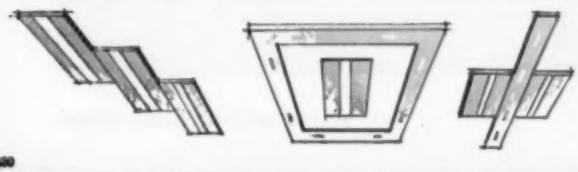

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(Continued from page 14A)

ing of the National Council held during their 13th Annual National Technical Conference in St. Louis. **Peter Simmons,** Dow Chemical Co., has been elected President; **Haiman Nathan** of Atlas Plastics, Vice-President; **R. K. Gossett** of Gossett and Hill, Secretary; and **Jules W. Lindau, III,** of Southern Plastics and the University of South Carolina, Treasurer.

The Parts Division of Sylvania Electric Products Inc. in Warren, Pa., has announced two recent appointments. **Merle W. Kremer** has been named general manager of the Division. **Richard E. Corcoran** has been appointed to the newly created position of product sales manager of wire and weld products.

At the recent annual meeting of the RLM Standards Institute, the following officers and trustees were elected: **Hoyt P. Steele,** President and Trustee (Benjamin Electric Mfg. Co.); **William P. Lowell, Jr.,** Vice-President and Trustee (Sylvania Electric Products, Inc.); **E. C. Huerkamp,** Treasurer and Trustee (Westinghouse Electric Corp.); **Burton G. Tremaine, Jr.,** Secretary and Trustee (The Miller Co.); **L. A. Hobbs,** Trustee (Smoot-Holman); **J. F. Whitehead, Jr.,** Trustee (Day-Brite Lighting Inc.); **D. E. Worrell,** Trustee (Quadrangle). **S. R. Naysmith** continues as Managing Director of the Institute.

The Lamp Division of Westinghouse Electric Corp., Bloomfield, N. J., has made several appointments in its various sections. **Raymond J. Stefany** has been named incandescent lamp manager of the commercial engineering section. **Mortimer Eber** has been appointed staff assistant to the manager of the lamp parts department of the Division. **Karl H. Neulinger** has been designated commercial engineering manager of the miniature lamp department. **Frank J. Camarata** has been named manager of manufacturing in the miniature lamp department. **Henry B. Kimball** has been appointed manager of equipment engineering and development of the Lamp Division.

Sylvania Electric Products Inc., Lighting Division, has established a new retail lamp sales organization, headed by **Herman L. Schreiner.** Mr. Schreiner will have his offices at the Division headquarters in Salem, Mass.

Russell Brittingham, Vice-President and director of purchases of Corning Glass Works, Corning, N. Y., has been chosen the next president of Pittsburgh Corning Corp. to succeed **H. B. Higgins.** Mr. Higgins is chairman of the board of Pittsburgh Plate Glass Co.

Purchase of Vancouver Lighting Co., Ltd., was announced by **John A. Wright,** president of Curtis Lighting, Inc. The Vancouver firm will become affiliated with Curtis Lighting of Canada, Ltd., Toronto, a wholly-owned subsidiary of the Chicago parent company. **F. D. Bolton,** Vancouver sales representative for Curtis Lighting of Canada, will be in charge of the sales and merchandising operations of the new plant.

The first presentation of two awards to be given annually for outstanding service to standardization and to standardization literature has been made by the Standards Engineers Society. Both awards for 1956 were made posthumously to **Dr. Dickson Reck,** editor of the new book, *National Standards in a Modern Economy.* The awards were made available by the American Society for Testing Materials.

The Standards Engineers Society also announces the election of 1957 officers. **Herbert G. Arlt,** Bell Telephone Laboratories, has been elected president. Secretary is **Jean A. Caffiaux,** Radio-Electronics-Television Manufacturers Association; treasurer is **Charles J. Lawson, Sr.,** International Business Machines Corp.; and **William E. Aksomitas,** Pratt and Whitney Aircraft Corp., has been elected director-at-large.

Dr. Lee L. Davenport has been appointed to an executive post with Sylvania Electric Products Inc. and will become President of Sylvania-Corning Nuclear Corp. upon its formation in the near future. The new organization is being formed as a jointly owned company by Sylvania and Corning Glass Works for expanded research, development and production activities in the atomic energy field. Dr. Davenport, formerly executive Vice-President of the Perkin-Elmer Corp., Norwalk, Conn., will have his offices at Sylvania's Atomic Energy Division headquarters in Bayside, Long Island.

The Lancaster Lens Co., Lancaster, Ohio, has acquired controlling interest in Indiana Glass Co., Dunkirk, Ind. **Robert K. Fox,** now president of Lancaster Lens, will become president of Indiana Glass. **George M. Morton** will be a Vice-President of both companies. No changes in operating personnel are planned at either plant.

Pittsburgh Reflector Co. has appointed **Ralph E. Smith, Jr.,** as Advertising Manager, with headquarters in the company's executive offices in Pittsburgh. **Myles R. Lees** has been named Production Control Manager and will supervise coordination of production facilities at the company's Irwin, Pa., plant. Pittsburgh Reflector also announces the ap-

(Continued on page 32A)

SPEAKERS at the New York Section Lighting Clinic, January 15, were: left to right, Professor C. C. Whipple, Brooklyn Polytechnic; Gene Beggs, Westinghouse Electric; Ernest Salter, E.T.L.; Miss Priscilla Presbrey, Westinghouse Electric; S. G. Hibben, Holophane; Professor Abraham Abramowitz, City College of New York; Willard Allphin, Sylvania Electric Products, and Bernard Boyland, General Electric Co. For details of the program, see February I.E., page 9A. Clinic was held at the Polytechnic Institute of Brooklyn.

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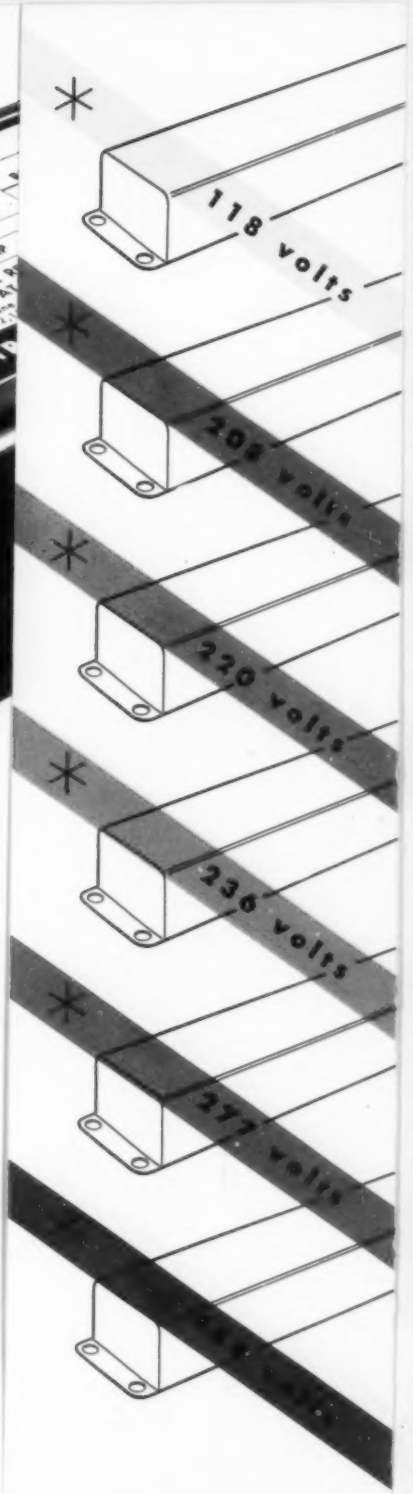

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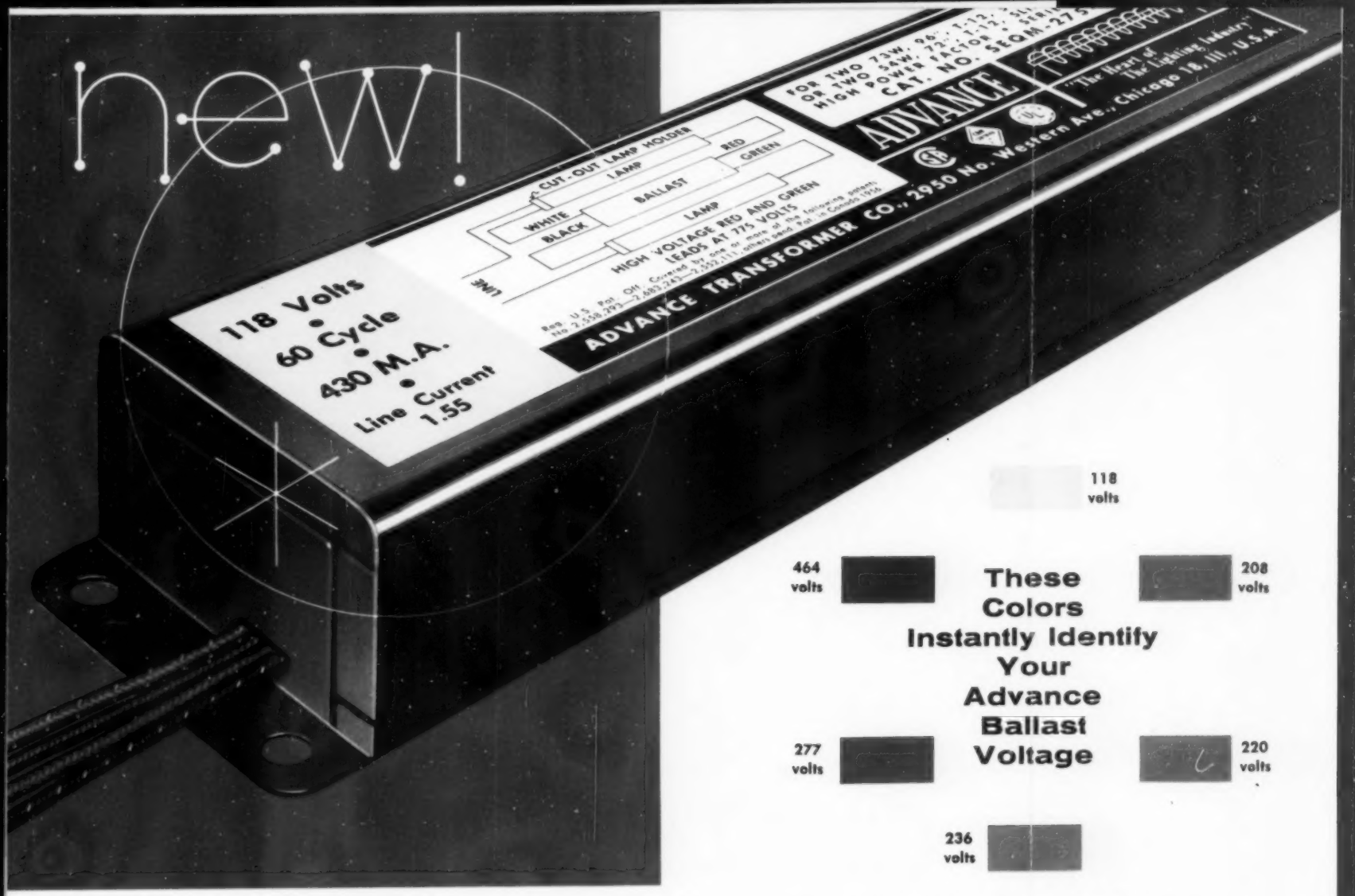

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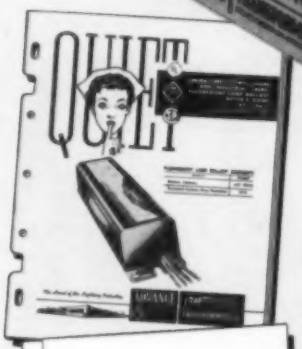
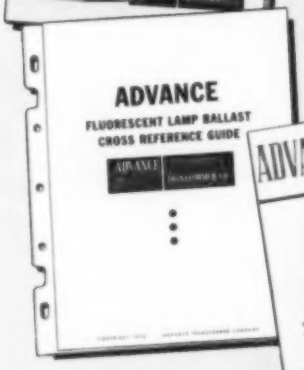
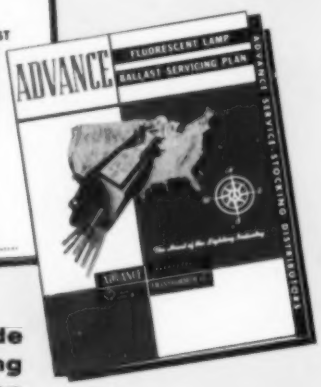


individual packaging

buyer's guide

cross reference replacement guide





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(Continued from page 18A)

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317 Baronne St., New Orleans, La. — *E. N. Avegno*

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107 Craig St., West
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(Continued from page 21A)

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(Continued on page 24A)

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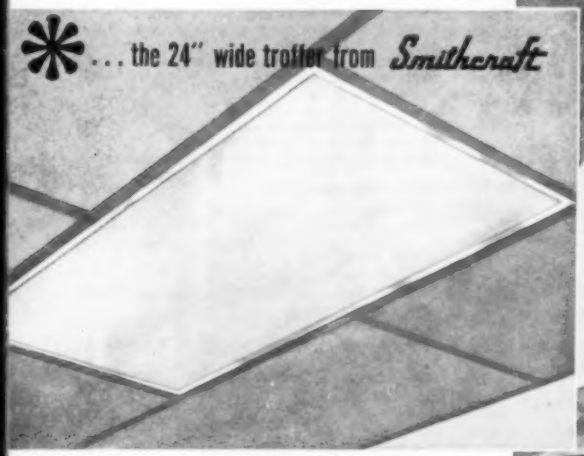

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New York 19, N. Y. *Edward Rambusch*

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Rochester 3, N. Y. *Horace W. Alexander*

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Cleveland 14, Ohio *Robert K. Farrington*

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Unistrut Products Company
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(*Continued on page 26A*)

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HOW YOU CAN SOLVE YOUR BALLAST HEATING PROBLEMS

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You as a lighting engineer, architect, contractor, fluorescent lamp user or fixture manufacturer and we as ballast manufacturers are concerned with the basic problem of ballast heating.

Overheating drastically reduces lighting efficiency, ballast life, and results in wasted lighting dollars for everyone. G-E ballast engineers have long recognized this problem and are working constantly to design ballasts that give more uniform heat dissipation and longer operating life.

Intensive research by General Electric engineers shows that the solution involves much more than a carefully designed ballast. Surveys of heating problems indicate many other trouble spots.

Some of these are: Improper ballast application . . . misuse of building insulation . . . poor lamp maintenance . . . improper fixture design.

The trend to higher fluorescent lighting levels and higher-output lamp sources in industrial and commercial applications is increasing daily. This means that it is more important to you than ever before to be provided with more dependable and economical ballast operation.

In this new illustrated bulletin, "Lets Talk About Ballast Heating," General Electric engineers have laid the facts on the table. They carefully describe, in simple, easy-to-read language, the causes of ballast overheating, the basic heat problem, and what happens to an overheated ballast. But, most important, they tell what **you** can do to help prevent overheating. To get your free copy just fill out the coupon and send it in. Your copy will be sent to you by return mail.

If you have a specific heating problem right now, why not contact your nearest General Electric ballast sales engineer? He'll be glad to answer your questions and tell you how General Electric longer-life ballasts can help you save lighting dollars.

General Electric Co., Section C401-37
Schenectady 5, New York

Gentlemen: Please send me a FREE copy of your bulletin, "Let's Talk About Ballast Heating," GED-3328.

NAME.....

COMPANY.....

POSITION.....

STREET.....

CITY..... STATE.....

Progress Is Our Most Important Product

GENERAL ELECTRIC

Sustaining Members (Continued from page 24A)

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H. A. Framburg & Co.
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Electric Supply Corporation
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Malley-Robinson Co.
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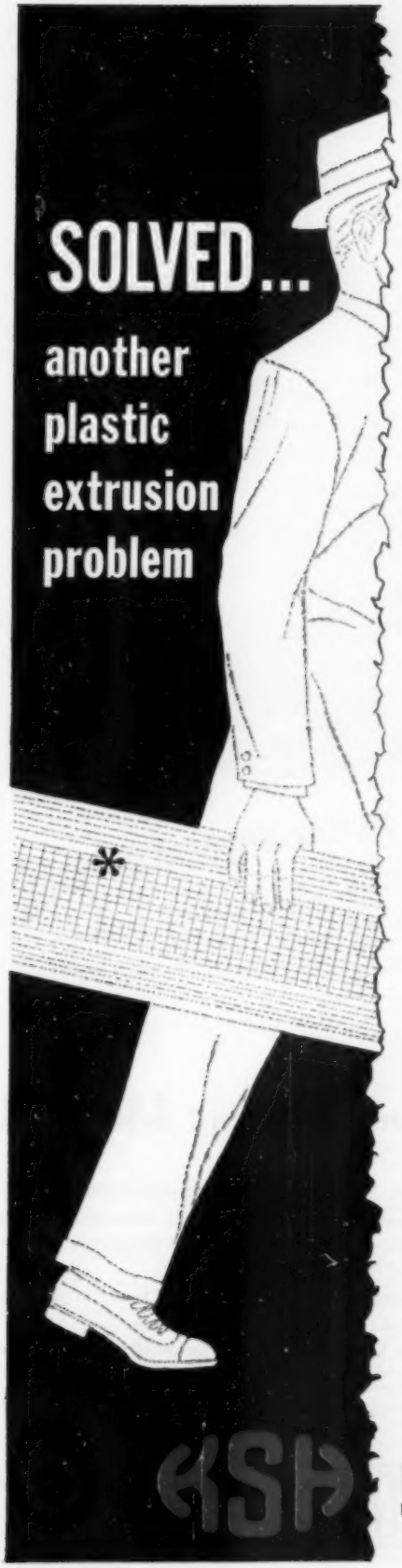
(Continued on page 29A)



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When you call in KSH on a plastic extrusion problem, you deal *first hand* with a design-minded executive-engineer, who gives you engineering advice and makes production decisions *then and there.*

Next time you need help... call The KSH Engineer On The Go for fast, *across-the-desk* action!

thanks to

the engineer on the go from KSH

...the man with authority to go *all the way!*

* light stable plastic extrusions available with transverse patterns as well as longitudinal markings.

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KSH **PLASTICS, INC.**
HIGH RIDGE, MO.

Manhattan's Third Avenue is the site of the world's longest fluorescent street-lighting installation. 750 fluorescent luminaires using Du Pont LUCITE illuminate the 7½-mile stretch. LUCITE extruded by Southern Plastics Co., Columbia, S. C., for Westinghouse Electric Corp., Lighting Div., Cleveland, O.

Better looking, better lighting

with luminaires using Du Pont LUCITE®

The longest fluorescent street-lighting installation in the world has been incorporated as part of the "face-lifting" program on Manhattan's Third Avenue. Luminaires using Du Pont LUCITE are spaced at 100-foot intervals on alternate sides of the 70-foot-wide avenue and run from the Brooklyn Bridge to the Harlem River, a distance of 7½ miles.

Extruded LUCITE acrylic resin is fabricated for use in each of the luminaires, which house four 72-inch, 100-watt fluorescent lamps. The luminaires are mounted 26 feet above the street and are tilted up 30 degrees from the horizontal and provide an average of 0.8 foot-candles of illumination on the street.

Du Pont LUCITE has remarkable strength and weather resistance. Its high shatter resistance reduces damage from vandalism, and its unique light-transmission properties produce better visibility, promoting safety for drivers and pedestrians.

LUCITE is being used in all types of modern lighting installations . . . modular light-diffusing panels, large-area lighting, lenses for troffer and pendant luminaires, side panels and protective elements for outdoor fixtures.

Why not incorporate the advantages of LUCITE in your own lighting designs?

SEND FOR FREE BOOKLET. A 12-page illustrated booklet describing property and application data on LUCITE acrylic resin for lighting is yours for the asking. For your free copy, write E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Dept., Room 433, Du Pont Building, Wilmington 98, Delaware.

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BETTER THINGS FOR BETTER LIVING
. . THROUGH CHEMISTRY

Sustaining Members — Distributors and Contractors

(*Continued from page 26A*)

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Allied Chemical & Dye Corp.
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Detroit 26, Mich. *Carl J. Schoeninger*

Dow Chemical Co.
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20 N. Carroll St.
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Los Angeles 12, Calif. *L. A. Rice*

Electrical Testing Laboratories, Inc.
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New York 21, N. Y. *Hoffman S. Beagle*

Fenestra Inc.
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Detroit 11, Mich. *E. W. Conover*

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Los Angeles 4, Calif. *Benn J. Hartmann*

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Cleveland 2, Ohio *E. L. Walter*

Franklin Design Service
Division of Safeway Stores, Inc.
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Accessory Equipment Dept.
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Bridgeport 2, Conn. *William B. Dexter*

General Fireproofing Co.
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Jeanette, Pa. *Donald H. Crock*

Thomas Keegan
20 Springdale Ave.
Massapequa, N. Y. *Thomas J. Keegan*

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Swissvale, Pa. *F. C. Ashe*

K-S-H Plastics, Inc.
Highway 30
High Ridge, Mo. *R. S. Hawes III*

The Leeds & Northrup Co.
4901 Stenton Ave.
Philadelphia 44, Pa. *Dr. R. C. Machler*

(*Continued on page 32A*)

SYLVANIA wall-to-wall lighting illuminates over 93,000 square feet of floor space in the new general office building of West Penn Power Company at Cabin Hill, Greensburg, Pa.

Here's a new approach:

Use wall-to-wall lighting

SYLVANIA Sylvan-Aire lighting system—shown here with optional V-shaped "sono-wedge" feature—offers sight and sound control in corridors as well as offices.

SYLVANIA lighting system, with its clean rows of white translucent plastic corrugated for rigidity, combines soft overall office illumination and an arresting functional appearance.

Sylvan-Aire lighting system: strip fixtures go in first

Support channels, "sono-wedges" are hung from fixtures

Corrugated white plastic is unrolled into channels

System will fit cleanly around air-conditioner diffusers, loudspeakers, etc.

Covers piping, wiring, yet leaves them easily accessible

Completed installation gives attractive functional lighting at *no extra cost.*

for all offices and corridors

Sylvan-Aire lighting system by Sylvania is used in striking treatment at new Cabin Hill, Greensburg, Pa., offices of West Penn Power Company

West Penn Power Company uses Sylvan-Aire wall-to-wall lighting to illuminate over 95% of the working area in its own new general office building at Cabin Hill, Greensburg, Pennsylvania.

A choice like this—by a major power company—marks a milestone in the development of modern lighting.

In planning their offices, West Penn Power management sought optimum working conditions for 600 executive and staff personnel. They located in an uncrowded area, away from big-city confusion, in the heart of their customer service area. They made a basic decision: that lighting is the environmental factor which most effects personnel, is most noticed by power company customers.

Architects Hoffman & Crumpton, Pittsburgh, together with consulting electrical engineers Carl J. Long Associates, specified wall-to-wall lighting for over 93,000 square feet of ceiling area. Included were all types of workrooms—general and private offices, corridors, and drafting rooms. Then electrical contractors Howard P. Foley Company selected Sylvan-Aire, Sylvania's wall-to-wall lighting system. With it they could meet all specs, bid low, then go on to effect untold savings in labor with Sylvania's *time-saving tool-free* hanging methods.

Sylvan-Aire by Sylvania brings West Penn Power a new and different office lighting. It maintains needed high footcandle levels with an overall light that is soft and diffused in quality. It creates a shadow-free, glare-free effect on desks and working surfaces. Its clean functional design presents a pleasing efficient appearance, helps promote good relations with employees and visitors alike.

More important—management saves on construction. They get equivalent of lighting and ceiling for cost of lighting system alone. They save on maintenance, too, because Sylvan-Aire is designed for ease of cleaning and lamp changing.

The Sylvania Fixture Specialist in your area is ready to talk over your individual lighting problems, and the latest developments in lighting systems—at your request. Give him a call. Or if you prefer, *write direct for your FREE copy of our complete new data book on "The Modern Method of Wall-To-Wall Illumination and Sound-Conditioning."*

SYLVANIA ELECTRIC PRODUCTS INC.
Lighting Systems, Dept. C30
One 48th Street, Wheeling, W. Va.

SYLVANIA

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LIGHTING • RADIO • ELECTRONICS • TELEVISION • ATOMIC ENERGY

Sustaining Members — Related Mfrs. and Miscellaneous

(*Continued from page 29A*)

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Waterbury, Conn. — *Richard L. Platt*

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Mississippi Glass Co.
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St. Louis 7, Mo. — *C. J. Youngblood*

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Plastics Division
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Newark 5, N. J. — *Arthur Meister*

Steel Window Institute
Cheltenham, Pa. — *George Hingston*

The Superior Electric Co.
83 Laurel St.
Bristol, Conn. — *William P. Carpenter*

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1957 Regional Conferences, I.E.S.

Region	Place	Date
Pacific Northwest	Empress Hotel Victoria, British Columbia	March 28-29
South Pacific Coast	Statler Hotel Los Angeles, California	April 3-5
Inter-Mountain	Alvarado Hotel Albuquerque, New Mexico	April 11-12
Southwestern	Holiday Inn Oklahoma City, Oklahoma	April 28-30
Midwestern	Pfister Hotel Milwaukee, Wisconsin	May 9-10
Great Lakes	Pantlind Hotel Grand Rapids, Michigan	May 13-14
Canadian	Sheraton Brock Hotel Niagara Falls, Ontario	May 16-17
East Central	William Penn Hotel Pittsburgh, Pennsylvania	May 23-24
Northeastern	Statler Hotel New York, New York	June 13-14

(*Continued from page 16A*)

pointment of **Walter M. Wyman, Jr.,** to the Philadelphia sales office.

Kurt Versen Co., Englewood, N. J. has named **Richard C. Anisfield** as Vice-President and National Sales Manager. Mr. Anisfield, who joined the company recently, was formerly an executive analyst with a management consulting firm.

A new product section to handle light arresters and cutouts has been organized within the General Electric Co.'s Distribution Transformer Dept., Pittsfield, Mass. General manager of the new section is **James A. Yunker,** former manager of the company's instrument transformer sales subsection at Lynn, Mass.

Appointment of **Wade Robbins** as a Field Engineer has been announced by Globe Lighting Products Inc. Mr. Robbins was previously district manager for the California Electric Co. of San Francisco.

Steber Manufacturing Co., Broadview, Ill., announces the appointment of **Robert J. Besal** as Field Sales Manager. Mr. Besal was formerly sales engineer.

L. D. Shank has been named general sales manager for National Electric Products Corp., Pittsburgh. In his new position, Mr. Shank assumes duties formerly handled by **R. C. Bennett, Jr.,** as vice-president of sales. Mr. Bennett is now general vice-president of National Electric.

The Miller Co. has appointed **Robert L. Kirshner** as manager of advertising and sales promotion. He succeeds **R. E. Owen,** merchandising manager.

The establishment of a new district sales office for lighting products on Long Island, and the appointment of **Edward H. Furbank** as district sales manager has been announced by the Lighting Division of Sylvania Electric Products Inc. Headquarters for the new district have been established at 244 Mineola Blvd., Mineola, N. Y. Also assigned to the new district are lamp sales representatives **V. F. Bangert, Lloyd Benett, William Dix** and **Edward Henderson,** and fixture sales representative **David Wick.** All men will have their offices at the Mineola address.

At the annual membership meeting of the Fluorescent Lighting Association, Inc., held January 16, the following directors were elected for the year: **Charles A. Pollack,** Pollack Luminescent Corp.; **Robert Cutler,** Cutler Sign Advertising

(*Continued on page 45A*)

The thinnest fixture ever designed with no dark areas

the new Gibson Ceilo • 35

This beautiful surface-mount fixture is only 2¾" deep, the thinnest ever designed without panels or strips to conceal the ballasts. In the Ceilo-35, the ballasts are mounted in the sides, an exclusive Gibson development which provides a smooth, unbroken panel of light.

Not only is this new fixture the best-looking you ever saw, it has many new and practical design features to make installation faster and maintenance easier.

,,,

WRITE TODAY FOR COMPLETE INFORMATION

Makers of the world's most versatile fixtures

ortho-77° 88°

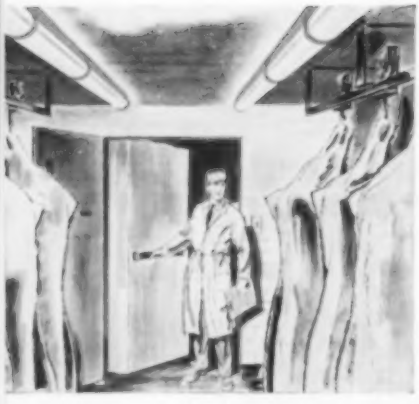
PAT. PEND.

Gibson LIGHTING

GIBSON Manufacturing Co.

1919 Piedmont Circle, N.E., Atlanta 9, Georgia

Now . . . a luminaire that operates in freezing temperatures!



The new Westinghouse LT operates in low or variable temperatures — making it ideal for lighting cold storage warehouses, food lockers, shipping platforms and marquees.

Designed in cooperation with the Refrigeration Institute, the Westinghouse LT luminaire gives low heat output and high light output. A clear, ribbed plastic enclosure protects the lamp from air currents to insure maximum efficiency of the F72T-12, 100-watt, rapid-start lamps. In addition, the LT's porcelain finish resists corrosion in moist atmospheres and enhances its appearance. Why gamble with fixtures that were designed for other purposes.

Doesn't the LT suggest an application to you?

For real lighting quality, specify the Westinghouse LT luminaire.

See your Westinghouse distributor or write, Westinghouse Electric Corp., Lighting Division, Edgewater Park, Cleveland, Ohio.

Look for other new Westinghouse lighting products . . . soon to be announced!

J-04399-B X

YOU CAN BE SURE...IF IT'S Westinghouse

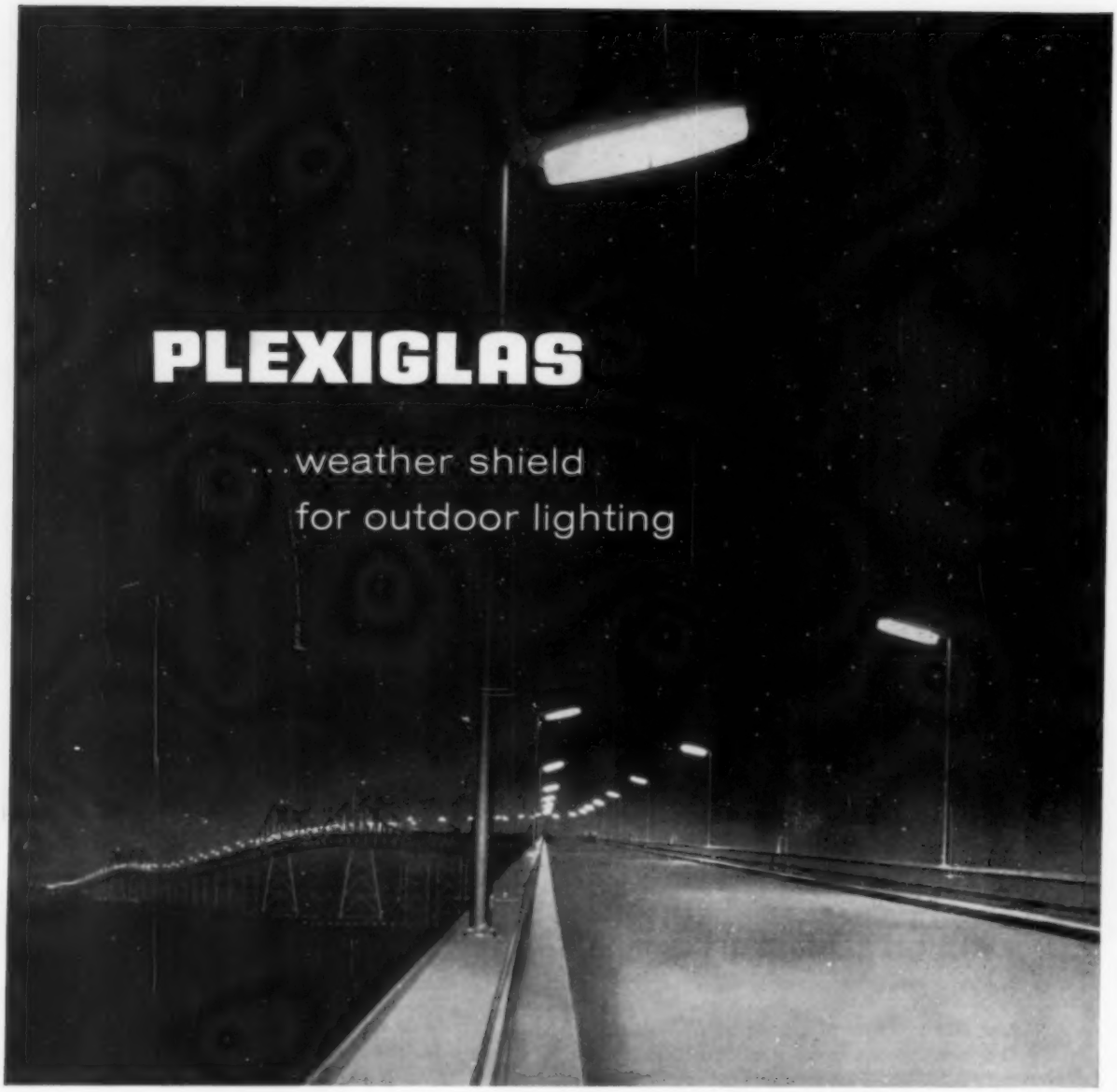
How HAPCO Aluminum Poles are paying off for the city of Olympia

When the citizens of Olympia, Washington, authorized a street lighting modernization program, Aluminum standards were recommended as the best answer to the city's particular needs. Located on Puget Sound, Olympia has a saline atmosphere, with a high sulfur content created by nearby timber products manufacturing operations. This presented a special corrosion problem which was reflected in upkeep costs of street lighting equipment. Previously, poles in this location required painting every two years. With HAPCO Aluminum Alloy Standards, no initial or maintenance painting will be needed.

Installation too, brought additional benefits to the city. Light weight HAPCO poles were assembled and wired by two men at a central location. A three man crew using a light duty boom handled the erection. During the progress of the job, part of the electrical distribution system was changed from underground to overhead without any design alterations to the poles. 115-volt festoon outlets were added on the job without difficulty. And, the installers report that pole adaptations to accommodate traffic control equipment, highway markers and other special equipment were made without special tools by mechanics of average skill.

Immediate and long range results like these have prompted cities all over America to specify HAPCO Aluminum Standards and Brackets for all types of lighting jobs. HAPCO poles are lighter, last longer, and fabricated to install with ease. Get the full story by asking for a copy of catalog HAL 754.

HUBBARD ALUMINUM PRODUCTS COMPANY
Division of Hubbard and Company
Pittsburgh 1, Pa.



Hundreds of fluorescent luminaires light the new Richmond-San Rafael bridge over San Francisco Bay. Durability is a requisite of these units. A vital component in their rugged construction is the large shield, molded of PLEXIGLAS® acrylic plastic. This shield protects lamps, sockets and ballasts from high winds, low temperatures, corrosion, dirt and bad weather.

Great strength . . . light weight . . . proven weatherability . . . freedom from discoloration . . . these are the reasons PLEXIGLAS shields are essential to top performance in outdoor lighting. Be sure the equipment you select—for streets and highways, parking lots, service stations, bridges—includes the advantages of PLEXIGLAS. We will be glad to send you the names of manufacturers who use this quality material in their luminaires, and a copy of our brochure "PLEXIGLAS for Outdoor Lighting".

Canadian Distributor: *Crystal Glass & Plastics Ltd., 130 Queen's Quay East, Toronto, Ontario, Canada.*

Chemicals for Industry

ROHM & HAAS COMPANY

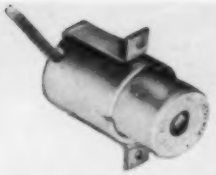
WASHINGTON SQUARE, PHILADELPHIA 5, PA.

Representatives in principal foreign countries

Channel Screw Terminal Type
for T-8 Lamps

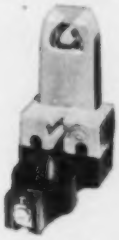
Channel "Quick Connect" Type
Rear Terminal Tabs for T-8 Lamps

Channel "Quick Connect" Type
Front Terminal Tabs for T-8 Lamps



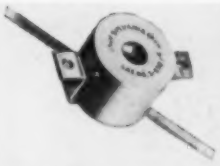
Slimline Plunger—Butt-on
High Voltage End Lead Terminal Type
—with or without mounting bracket
for Slimline Lamps

Medium—Single Screw Terminal
Type for T-8 and T-12 Lamps



Medium—Combination Screw Terminal
Type for T-8 and T-12 Lamps

Medium—Butt-on
Lead Terminal Type
for T-8 and T-12 Lamps



Slimline Plunger—Butt-on
Low Voltage End Lead Terminal Type
—with or without mounting bracket
for Slimline Lamps

Sylvania fills every basic need for

Fluorescent Wiring Devices

Slimline—Butt-on High Voltage End
Screw Terminal Type
for Slimline Lamps

Slimline—Butt-on Low Voltage
End Screw Terminal Type
for Slimline Lamps

- Sylvania's complete line can provide the exact lamp holder or starter socket to meet your requirements.

These wiring devices are carefully manufactured to Sylvania's exacting standards, and are approved by Underwriters' Laboratories and Canadian Standards Association Approvals Laboratories.

When you need the best in fluorescent wiring devices, see Sylvania. For complete details and specifications, write for catalog.

Slimline Fixtures High Voltage End
Screw Terminal Type
for Slimline Lamps

Slimline Fixtures Low Voltage End
Screw Terminal Type
for Slimline Lamps

Medium—Separate
Lead Terminal Type

Medium—Butt-on
Lead Terminal Type
—with or without mounting bracket

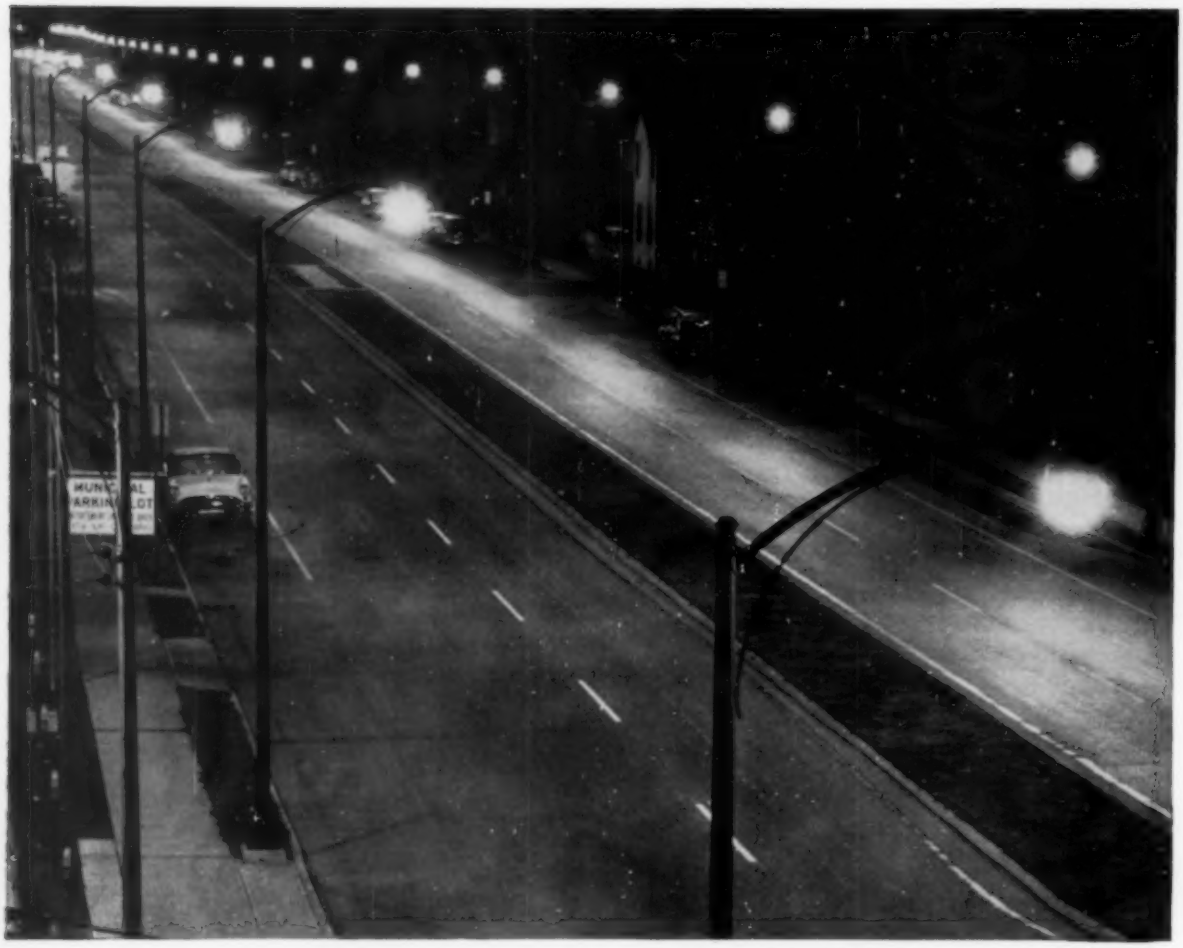
SYLVANIA

PARTS DIVISION

Sylvania Electric Products Inc., Parts Division, Warren, Pennsylvania

SPECIAL WIRE · METAL STAMPINGS · MOLDED PLASTIC · ELECTRONIC COMPONENTS

4-way service from one source



Modern highway controlled-beam luminaire lighting directs light evenly on the desired area.

Controlled-beam luminaire design puts light where it does the most good

Tonight, as a responsible citizen, take a professional look at the lighting on your streets and highways.

If you see aimless patterns of light outside of the road and sidewalk area, instead of a clear light pattern as in the picture, your lighting needs up-dating.

And the sooner you give attention to this vital area of civic management, the sooner you'll get benefits in reduced night accidents and crime rates.

Old-fashioned luminaires, that you see too tragically often, do little to solve the problems of street and highway lighting. Uncontrolled, the light drifts off uselessly into too many directions where it's wasted.

The way to get the kind of lighting that does the most good per dollar is with controlled-beam luminaires. These involve much more than a protective glass enclosure. They require a refractor working in combination with a reflector to control light distribution according to the type of illumination that's needed.

You get better lighting efficiency with less distraction for motorists and pedestrians.

Corning Lighting Engineers design refractors to A.S.A.-I.E.S. standards. Our production facilities turn out the finished units with the design molded accurately in permanently durable glass.

Ask a street lighting equipment manufacturer to show you how modern street lighting can make your city brighter and better and safer for everyone.

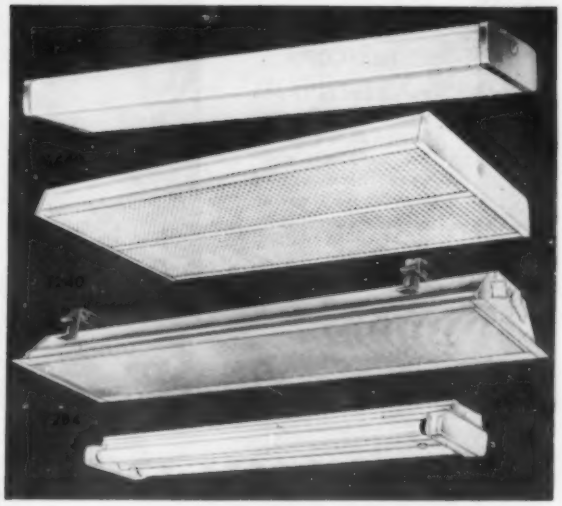
CORNING GLASS WORKS, 35-3 Crystal Street, **CORNING, N.Y.**

Corning means research in Glass

PLANNED STORELIGHTING IS KEY TO GREATER SALES!

Carefully planned lighting plays a vital role in every area of modern retail selling—to call attention to a store window, to accent color and textures in a dress shop, to make china, glassware or silver sparkle on the shelves, to bring out the appetizing color of a T-bone steak at the meat counter.

Miller's versatile Merchandise Line—combining the best in general fluorescent lighting with a good assortment of accent downlights—makes it simpler than ever before to plan and specify the finest lighting for any retail client. Write for our new Storelighting brochure!



miller
SINCE 1944

Better Lighting for a Brighter America®

THE MILLER COMPANY • GENERAL OFFICES: MERIDEN, CONN. • FACTORIES: UTICA, OHIO and MERIDEN, CONN. • IN CANADA: CURTIS LIGHTING OF CANADA LTD., TORONTO

RAPID-START
COMPRESSIBLE
Rated at 600 volts-660 watts. Designed to accept T17 envelope and give shortest back-to-back spacing for Power-Groove Lamps. ALF 822 series.
RAPID-START
TELESCOPIC
Rated 600 volts-660 watts. ALF 812 series. Design of this holder provides proper clearance from mounting area for the larger diameter of Power-Groove Lamps.

NEW HOLDERS DESIGNED FOR POWER-GROOVE FLUORESCENTS

General Electric offers telescopic and compressible lampholders compatible in size and weight with new F48TG17/RS Power-Groove Lamps

The rugged construction of these new holders gives them greater strength than existing units. Yet minimum back-to-back dimensions of the compressible type sharply reduce dark area. Both units feature double wiping silver-plated contacts adequate for new, higher lamp currents. See illustrations for details.

Information on this new family of General Electric fluorescent lampholders can be obtained by addressing Accessory Equipment Department, General Electric Company, Bridgeport 2, Connecticut.

Progress Is Our Most Important Product

GENERAL ELECTRIC

"DECIDEDLY BETTER"
DAY-BRITE
Lighting Fixtures

DAY-BRITE LIGHTING MAKES THE BIG DIFFERENCE HERE

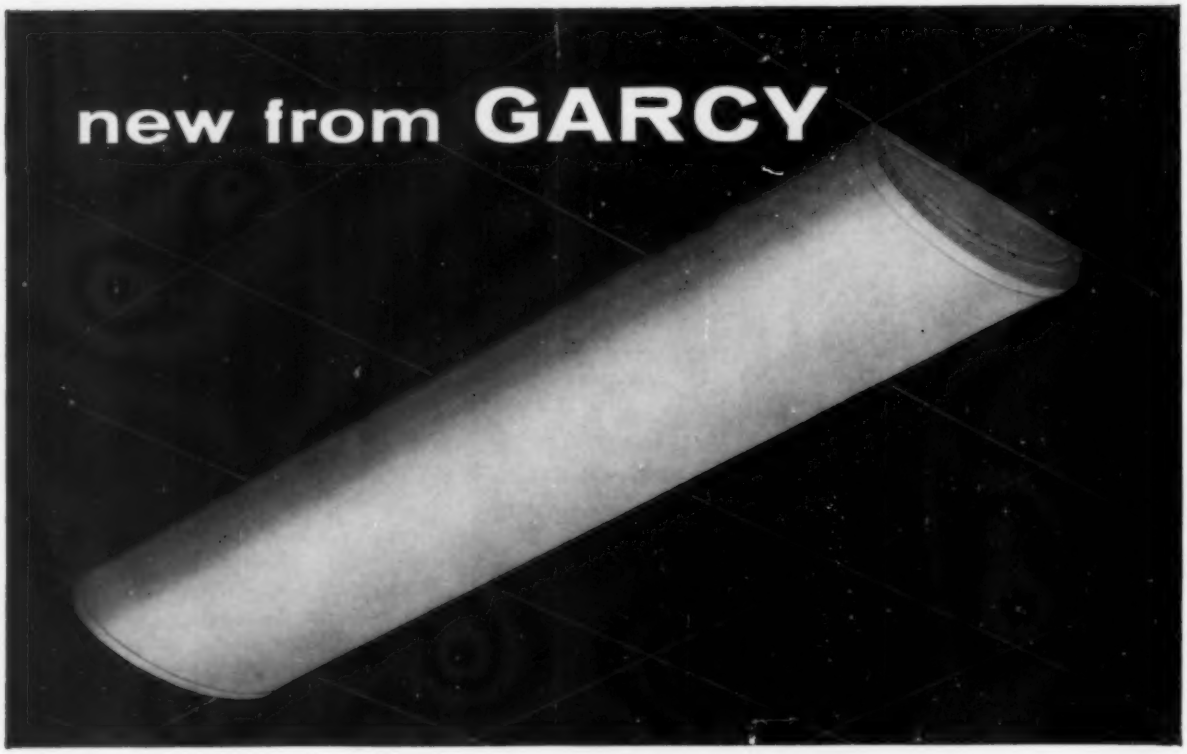
Where only the best is good enough

More so than in any other area of good lighting, the nation's schools occupy the No. 1 spot. That's why school lighting is all-important—to the citizens of tomorrow and the teachers of today. Both do a better job when light is right.

Because of this, it is doubly important to choose the best in lighting. That means Day-Brite—you can easily prove this to yourself by making a point-by-point comparison between Day-Brite and any other make. Call your Day-Brite representative—he'll gladly show you many reasons why Day-Brite is your logical choice. Day-Brite Lighting, Inc., 5432 Bulwer Avenue, St. Louis, Missouri.

NATION'S LARGEST MANUFACTURER
OF COMMERCIAL AND INDUSTRIAL
LIGHTING EQUIPMENT

Typical classroom, Archbishop Hoban High School, Akron, Ohio, lighted with Day-Brite fixtures.
71105



As ceiling heights go down Ultra-Lux goes up

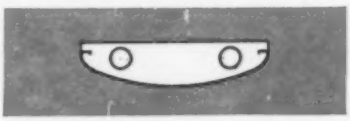
The trend to lower ceiling heights in schools and office buildings calls for a new shallow lighting fixture. Low ceilings rule out conventional pendant mounted units. Shallow ceiling construction does not permit recessed fixtures.

Surface-mounted Ultra-Lux, with its shallow profile, provides an attractive and efficient answer . . . gives a recessed appearance at surface-mounted cost. Its gently curved shield of polystyrene seems to recede into the ceiling.

With its translucent polystyrene shield, Ultra-Lux provides efficient light transmission and uniform distribution. The uniform surface brightness of Ultra-Lux is well within acceptable limits for glare-free comfort.

Light in weight, light in appearance, sturdily built, and easy to install, Ultra-Lux fixtures may be installed in single units or joined in continuous runs. Concealed hinges simplify cleaning and relamping.

Recessed Appearance
Surface-Mounted Cost

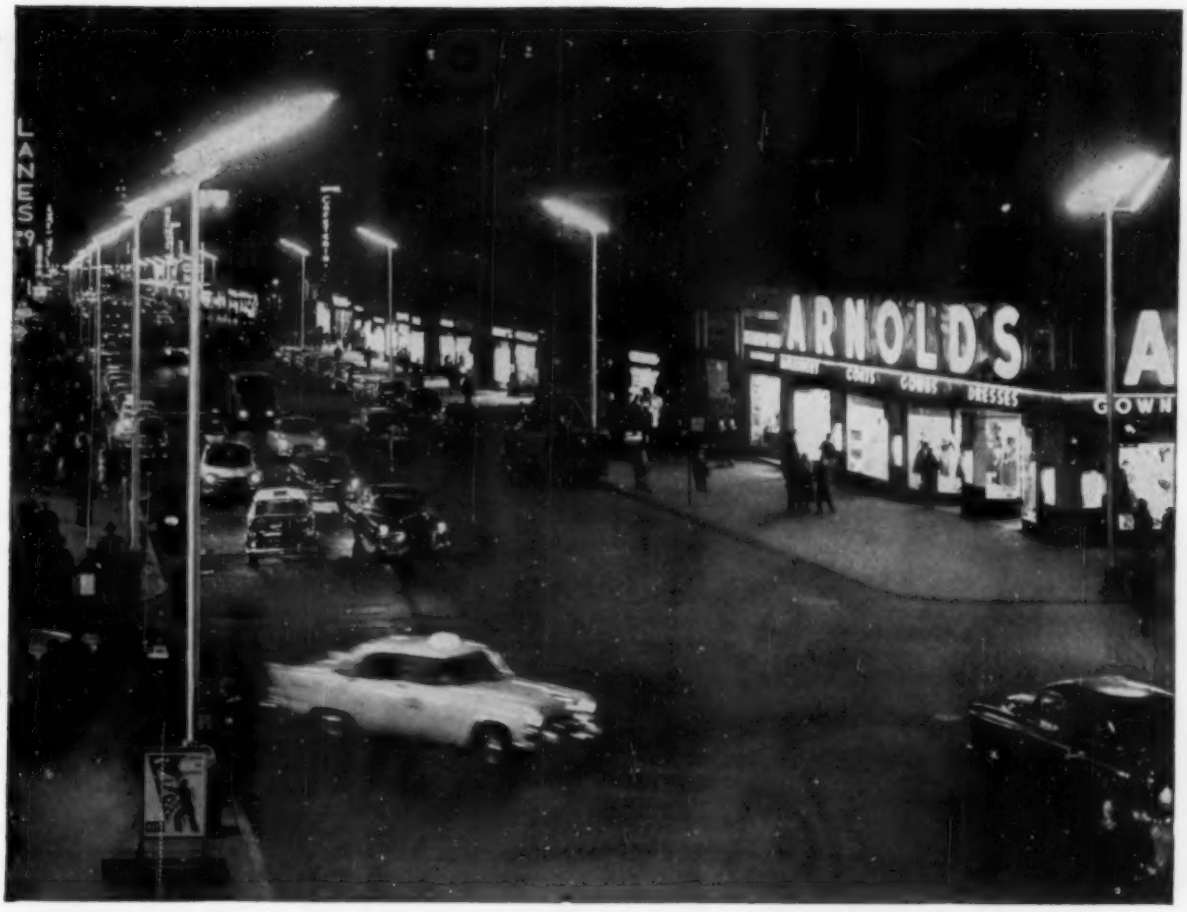


GARCY Ultra-Lux
Total Depth 3¼"

GARCY
Preferred for Performance

COMPLETE
COMMERCIAL
LIGHTING

Garden City Plating and Manufacturing Company
1760 North Ashland Avenue • Chicago 22, Illinois
In Canada: Garcy of Canada, Ltd., 1244 Dufferin Street, Toronto 4



New York City's "14th Street Association" proves modern whiteway lighting pays big dividends

With the use of P & K aluminum standards and LUXaire® Fluorescent Luminaires, the average light level on 14th Street, a major downtown shopping center, has been increased from 0.4 to better than 2 foot candles. The P & K LUXaire® units, specially designed in wedge shape, are mounted at 30-foot height on staggered 70-foot spacings.

The choice of P & K equipment, combining high strength with light weight, permitted the use of existing electrical vaults with a minimum of excavation and foundation work. Installation was quick, easy, and low in cost. Negligible maintenance requirements, a feature of all P & K products, will serve to keep the *real* cost of lighting equipment on 14th Street surprisingly low.

Comments from the 14TH STREET ASSOCIATION, who paid for the new lighting: "New White way has accomplished its purpose . . . business improvement . . . enhanced shopping area . . . safer for shoppers and vehicular traffic. . . ."

WRITE FOR A COPY OF THE P & K LUXaire® Catalog . . . and use the P & K planning and advisory services without obligation.

P&K PFAFF & KENDALL

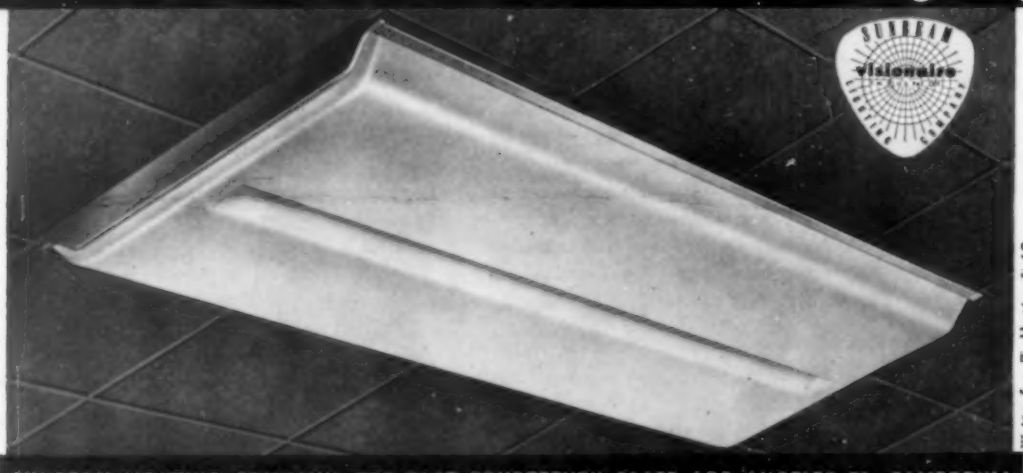
84 FOUNDRY ST., NEWARK 5, N. J.

CONTEMPORARY LIGHTING WITH AMAZING SIMPLICITY

Here's surface-mounted lighting with a big difference: the luminous, all-white SHALLORAMA.® A new Sunbeam Lighting development, it represents a never-before-achieved combination of extreme shallowness and unusual even brightness control. Designed for new or remodelled interiors, it is especially suitable to today's trend to lower ceilings. All metal components are die-formed for uniform, precision construction. The matte white, wrap-around Plexiglas is sturdily framed and has continuous hook-on ledges for opening from either side. No hooks, hinges, latches, light or dark streaks mar the sleek SHALLORAMA® beauty.

Installation is a swift and simple procedure: remove assembled fixture from carton, secure to ceiling with normal two-screw mounting, attach leads and the job is done. Don't worry about uneven ceilings either; the integral jack-type levellers assure precision alignment.

Patent Pending **SHALLORAMA a new dimension in lighting**



Write for Bulletin A-63.

SUNBEAM LIGHTING COMPANY, 777 EAST FOURTEENTH PLACE, LOS ANGELES 21, CALIFORNIA

(*Continued from page* 32A)

Co.; **Harry Weiss,** Supro Lux Mfg. Co.; **Abner A. Byer,** Cold Cathode Lighting Corp.; **N. Marshall,** Sola Electric Co.; **David Cutler,** Cutler Electrical Products, Inc.; **Miles Pennybacker,** Voltarc Tubes, Inc. The directors then elected Mr. Weiss as President, Mr. Robert Cutler as Vice-President, Mr. Pennybacker as Treasurer. **Julian C. Ruben** was elected Executive Secretary.

J. W. Cosby has been named manager of arc carbon sales for National Carbon Co., Division of Union Carbide and Carbon Corp. He succeeds **E. R. Geib,** who has been appointed arc carbon sales consultant.

Deaths

William W. Hanscom, Golden Gate Section.
D. A. McCall, Jr., Southwestern Section.
W. R. Mook, Southwestern Section.
Borge Nielsen, Twin City Section.
Wilfred F. White, Cleveland Section.
C. A. Yunker, Ohio Valley Section.

BOOKS AND PAMPHLETS

Lichtarchitektur, by Dr. Walter Koehler and Wassili Luckhardt, published 1956, in German, by Beuwelt Verlag der Ullstein A. G., Berlin, West Germany. 232 8¼ x 10¾-inch pages, 224 illustrations, many graphs and tables.

Approximately one-half this book is devoted to excellent photographic illustrations of light and lighting from various parts of the world, some of which exemplify illumination of architectural designs, others the creation of architectural effects through lighting.

The authors proceed to show that lighting and architectural design must be integrated, and proper integration can not be achieved when the latter is carried out independent of lighting considerations.

To create architectural effects with light, that is, to utilize those properties of light and light-controlling media conducive to creating architectural effects, requires compromise and cooperation between architects and well-trained lighting engineers. Their efforts should be coordinated in the preliminary stages of the work. Optimum lighting results can rarely be achieved when the illumination problem is preconditioned by architectural design attained without careful consideration of the architectural effects achievable through well-planned lighting. This emphasizes the need for cooperation between lighting engineers who will seek to understand the architects' viewpoint and architects who will solicit the lighting engineers' aid in attaining an aesthetic treatment through ingenious application of light, color and shadow, in short, by the creation of architectural effects in space.

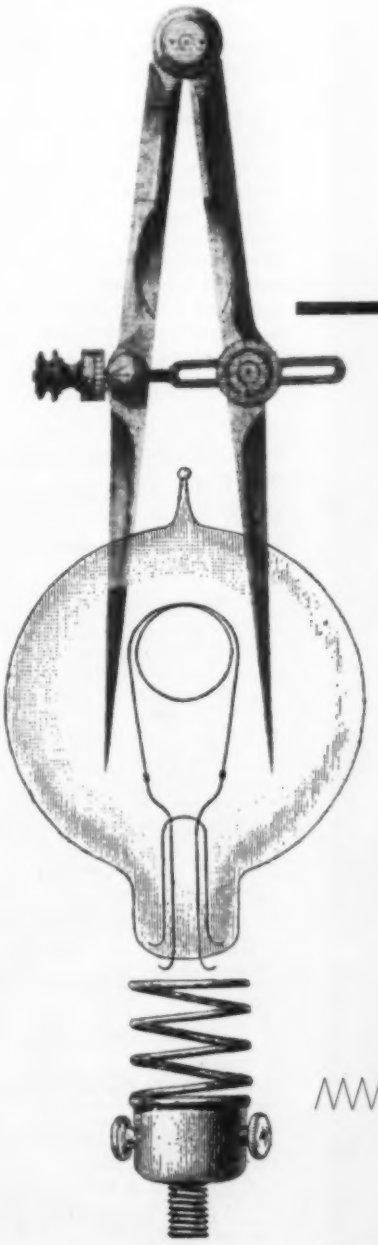
The first half of the book devoted to a pictorial representation of light and lighting, serves to show how light is used as a building block to achieve various results. The second part discusses and illustrates how light is used to achieve architectural effects in space. Finally various categories of present-day interior lighting are discussed and illustrated.

Mathematical treatment does not exceed simple applications of the calculus, so that the book is likely to be of interest to most trained illuminating engineers, photographic scientists, and especially architects and interior decorators.

RLM Standard Specifications for Industrial Lighting Units, available from the RLM Standards Institute, 326 West Madison St., Chicago 6, Ill. No charge.

This current edition of RLM Specifications contains revisions in specifica-

(*Continued on page* 46A)



WE DON'T OWN THIS PATENT!

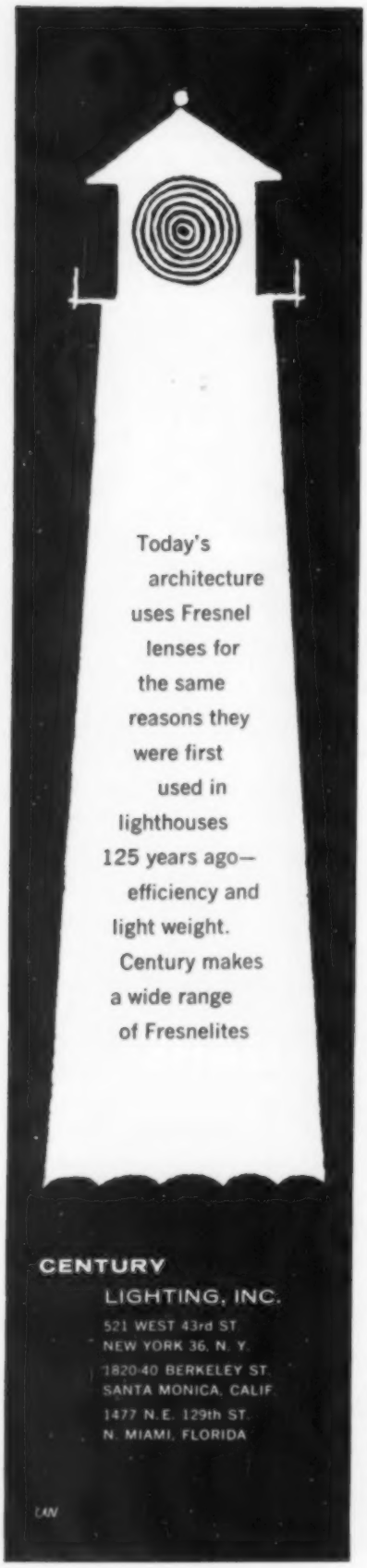
But we do have many exclusive patented features. They developed from our dedication to the utilization and control of incandescent light.

Our recessed, indirect, swivel, hospital and general purpose lighting units are skillfully engineered to utilize the maximum amount of light. They offer flexibility of application, ease of installation, trouble-free maintenance and designed simplicity.

Kurt Versen fixtures are competitively priced.

Write for our catalog.

Kurt Versen Company
contemporary lighting®
Englewood 5, New Jersey


Today's architecture uses Fresnel lenses for the same reasons they were first used in lighthouses 125 years ago— efficiency and light weight. Century makes a wide range of Fresnelites
CENTURY LIGHTING, INC.
521 WEST 43rd ST.
NEW YORK 36, N. Y.
1820-40 BERKELEY ST.
SANTA MONICA, CALIF.
1477 N.E. 129th ST.
N. MIAMI, FLORIDA

(Continued from page 45A)

tions for both incandescent and fluorescent industrial lighting units. New coefficient of utilization tables are given for eight different units, based on the Zonal Method.

Electric Power from the Atom, published by the Edison Electric Institute, 420 Lexington Ave., New York 17, N. Y. No charge.

This 32-page booklet discusses the progress of the industry's program to produce electrical power with atomic fuel. Illustrated with maps, charts and drawings, the text deals primarily with five basic questions — how important is it, how is it made, what about its cost, when can we expect it, and what is being done to develop it.

See Your Home in a New Light, revised edition, published by the General Electric Co., and available through G-E Large Lamp Sales District offices.

Home lighting recipes in this third edition have been expanded to include information designed to fit the latest trends in decoration and furniture arrangement and to incorporate recent developments in engineering of lighting for the home.

NEW MEMBERS

At the meeting of the I.E.S. Council held at New York, N. Y. on February 14, 1957, the following were elected to membership. Names marked * are transfers from Associate Member Grade.

ALABAMA CHAPTER

Associate Members:

Dorn, M. E., Mayer Electric Supply Co. Inc., Birmingham, Ala.

Dunagan, C. E., Moore Handley Hardware Co. Inc., Birmingham, Ala.

ARIZONA SECTION

Associate Members:

Forsyth, R. L., Electrical Engineering & Sales Corp., Phoenix, Ariz.

Perreault, A. J., Jr., New State Electric, Phoenix, Ariz.

Stone, J. F., Graybar Electric Co. Inc., Phoenix, Ariz.

ARK-LA-TEX CHAPTER

Associate Member:

Hardaway, H. E., Westinghouse Electric Supply Co., Shreveport, La.

BRITISH COLUMBIA SECTION

Associate Members:

Edwards, J. S., J. S. Edwards Co., Vancouver, B. C.

Mackie, S. W., Lighting Materials Ltd., Vancouver, B. C.

CENTRAL NEW YORK SECTION

Associate Member:

Mahoney, P. J., Hubbard & Co., Pittsburgh, Pa.

CHICAGO SECTION

Associate Members:

Bell, H. A., Commodore Electric Co., Chicago, Ill.

Sancraint, M. S., Westinghouse Electric Corp., Chicago, Ill.

Sullivan, C. E., Benjamin Electric Mfg. Co., Chicago, Ill.

CLEVELAND SECTION

Associate Member:

Lloyd, F. J., Jr., Allen Electric Co., Cleveland 15, Ohio.

CONNECTICUT SECTION

Associate Members:

Guidoux, D. S., Fletcher Thompson, Inc., Bridgeport, Conn.

Johannsen, C. E., The United Illuminating Co., New Haven, Conn.

CORNHUSKER SECTION

Associate Members:

Baker, J. M., Westinghouse Electric Corp., Omaha, Nebr.

Gibb, J. M., North Central Chapter NECA, Omaha, Nebr.

Grenier, L. S., Rogers Electric Supply, Sioux City, Iowa.

Fuchser, F. E., Leo A. Daly Co., Omaha, Nebr.

Hossack, W., Thompson Electric Co., Sioux City, Iowa.

Johnson, Paul, Electric Engineering Co., Sioux City, Iowa.

Sewa d. R. A., John Latenser & Sons, Omaha, Nebr.

Smith, E. L., Graybar Electric Co. Inc., Sioux City, Iowa.

EASTERN NEW YORK SECTION

Associate Member:

Colfer, J. E., Henzel Powers Inc., Albany, N. Y.

EASTERN PENNSYLVANIA SECTION

Member:

Bonarrigo, A. R., Lacy, Atherton & Davis, Harrisburg, Pa.

Associate Members:

Fix, H. N., Medlar Electric Co., Reading, Pa.

Hamsher, R. C., Pennsylvania Power & Light Co., Harrisburg, Pa.

Knipe, G. E., Westinghouse Electric Supply Co., Allentown, Pa.

Lyons, D. K., Graybar Electric Co., West Reading, Pa.

Monde, R. G., Jr., Graybar Electric Co. Inc., West Reading, Pa.

Walenta, R. C., Graybar Electric Co. Inc., West Reading, Pa.

EDMONTON CHAPTER

Associate Members:

Halkier, G. K., Johnson Bros. Electric Co. Ltd., Edmonton, Alta.

Stafford, A. H., Canadian Utilities Ltd., Vegreville, Alta.

FLORIDA SECTION

Associate Member:

Kerlikoske, R. W., Florida Power & Light Co., Sarasota, Fla.

FOREIGN NON-SECTION

Associate Members:

Pring, T. W. E., London Electricity Board—Southern Sub Area, Beckenham, Kent, England.

Wicks, S. T., The Crompton Engineering Co. (Madras) Ltd., Madras, India.

GEORGIA SECTION

Associate Members:

France, D. M., Atlanta Fluorescent Co., Atlanta, Ga.

Outrau, Sy., Atlanta Lighting & Fixture Co., Atlanta, Ga.

HAMILTON ONTARIO CHAPTER

Associate Member:

Campbell, L. S., Zenith Electric Supply Ltd., Brantford, Ont.

HEART OF AMERICA SECTION

Associate Member:

Arehart, C. L., C. L. Arehart Co., Kansas City, Mo.

INLAND EMPIRE CHAPTER

Associate Member:

Schneider, J. H., The Crescent, Spokane, Wash.

MARITIME CHAPTER

Associate Member:

Dixon, C. F., Canadian General Electric Co., St. John, N. B.

MARYLAND SECTION

Associate Members:

Ellison, R. J., Egli & Gompf, Inc., Baltimore, Md.

Lang, J. D., The Union Metal Mfg. Co., Baltimore, Md.

Little, E. T., Central Electric Co. Inc., Baltimore, Md.

MIAMI VALLEY CHAPTER

Associate Member:

Houser, D. W., The Miller Co., Meriden, Conn.

MICHIGAN SECTION

Associate Members:

Grossfeld, W. H., General Light Supply Co., Detroit, Mich.

Dunn, J. W., Motor City Electric, Ann Arbor, Mich.

Perkins, J. A., Verd-A-Ray Corp., Toledo, Ohio.

Rooney, R. B., The Detroit Edison Co., Mt. Clemens, Mich.

Violassi, A. J., Yamasaki, Leinweber & Associates Inc., Royal Oak, Mich.

Student Members:

Baker, H. R., S. W. Seeley Co., Grosse Pointe Woods, Mich.

McInnes, R. C., University of Michigan, Ann Arbor, Mich.

MID-SOUTH CHAPTER

Member:

*Fletcher, J. F., Flinn, Fletcher, Humphrey, Inc., Memphis, Tenn.

Associate Member:

Huddleston, V. L., Sylvania Electric Products Inc., Memphis, Tenn.

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(*Continued on page* 48A)

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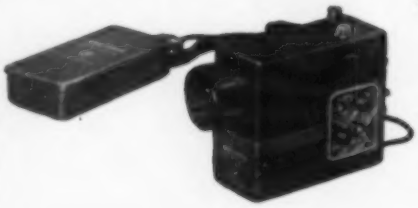

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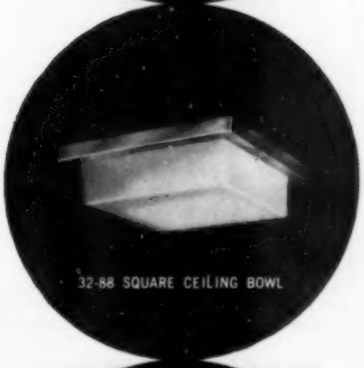

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Permanent satin finish . . . maintenance-free operation . . . durability . . . these are some of the inherent advantages of mcPhilben cast aluminum lighting units. McPhilben quality construction and built-in extras can help solve many of your lighting problems.

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(*Continued from page 48A*)

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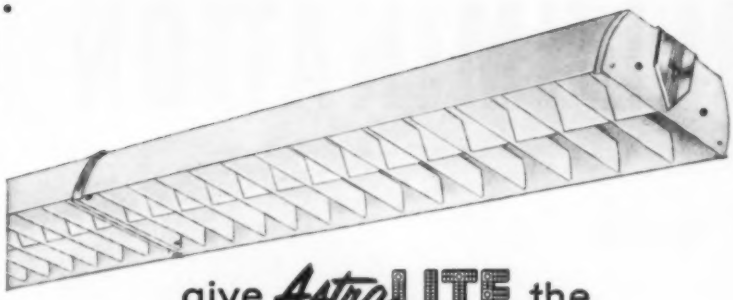

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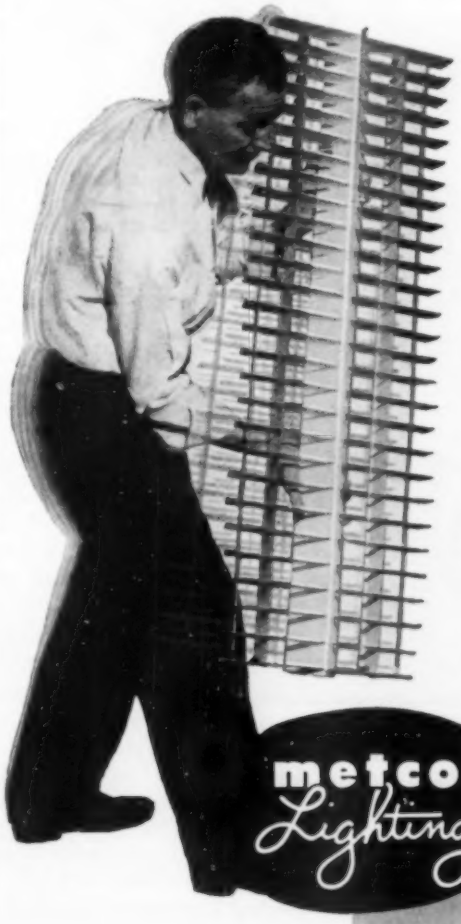

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Increasingly you will see another emblem, diamond shaped, with the words "CBM CERTIFIED by ETL." This emblem identifies the ballast as one which meets rigid performance specifications set forth by Certified Ballast Manufacturers to assure optimum lamp and ballast operation.

Many manufacturers are now making ballasts which carry only the UL emblem. These ballasts are often referred to as "UL Ballasts" or erroneously, as "UL-approved" ballasts.

In order to save a few nickels per ballast, many people are buying these non-certified ballasts, apparently under the impression that UL listing signifies approval of design and construction characteristics upon which satisfactory lighting performance depends. It does not.

The truth is that Underwriters Laboratories do perform a valuable, but highly specialized function in testing ballasts. UL listing indicates only that safety requirements are met. UL does not test for any operating characteristics that assure efficient, economical performance and long lamp life.

How, then, can you be sure that a ballast will meet the quality standards necessary to insure efficient performance? The answer is simple: buy ballasts that are certified to meet CBM specifications wherever such specifications exist.

Without CBM specifications there are no standards for lumen output, lamp life, peak to RMS ratio (wave shape), starting voltage...

no floor under quality. CBM certification assures the user that a ballast will meet or exceed accepted minimum standards on all these factors.

The actual COST of non-certified ballasts? We invite you to GET THE FACTS. We have prepared an engineering report, carefully and accurately calculated from figures published by a leading company who makes non-certified ballasts. Their own figures show that the lamp life of non-certified ballasted lamps is reduced as much as 28%; light output by as much as 13%, compared with certified CBM ballasts used in the same installations.

Calculated in operating costs, our report shows that while the initial cost of non-certified ballasts may be pennies less, their actual cost is many dollars more in terms of reduced lumen output and long lamp life alone.

The Sola Electric Co. has no "double standard" of quality for lighting ballasts. In addition to being UL listed, EVERY Sola ballast for general lighting applications meets or exceeds CBM specifications - and is so certified - in every case where CBM specifications or proposed specifications exist. You are assured optimum lamp performance and efficient, economical ballast operation with every Sola ballast you buy.

GET THE FACTS...write today for Sola's engineering report on the real cost of non-certified fluorescent lighting ballasts.

Sincerely yours,

SOLA ELECTRIC CO.

L. C. Marschall
Executive Vice President

LCM:vm

P.S. Would you like other members in your organization to have a copy of Sola's engineering report on the real cost of non-certified ballasts? Please indicate the number of copies you require. We will be happy to mail them to you.

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CERTIFIED CBM BALLASTS assure more satisfactory and economical fluorescent lighting.

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Send for free booklet, "Why It Pays to Use CERTIFIED CBM BALLASTS in Fluorescent Lighting Fixtures".

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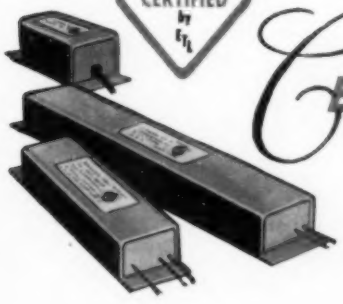

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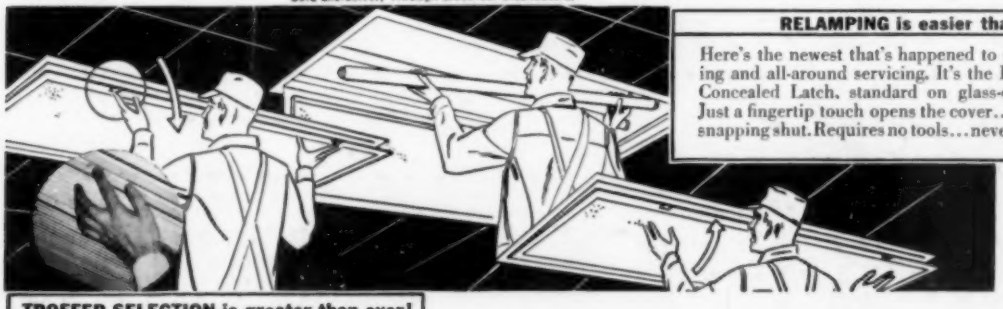

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